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VOLUME 14

1927

PUBLISHERS  
AMERICAN MEDICAL ASSOCIATION  
CHICAGO, ILL.





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## THE MODE OF ORIGIN OF GALLBLADDER LESIONS \*

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NEW YORK

Much has been written about infection of the gallbladder, but a fairly extensive review of the literature failed to discover descriptions of infectious lesions of the gallbladder in the absence of stones.

The present study of gallbladder lesions was undertaken with the purpose of determining by what processes some of the commonly observed lesions and pathologic states of the gallbladder are produced. At the outset it was thought that a correlation of bacteriologic and histologic examinations of the gallbladder would give this information but discrepancies soon became apparent. Bacteria were often cultivated from gallbladders that showed no lesions and obviously pathologic ones often yielded negative cultures. The micro-organisms cultivated were almost always intestinal or mouth bacteria and in surgical material, manipulation of the gallbladder and duct at the operation made it impossible to exclude contamination from the duodenum. Collateral study of the clinical histories, the operation notes of surgeons and the gross and histologic conditions in the gallbladders gave much more connected and useful information.

Analysis of the clinical histories and operation notes revealed several relevant facts. Recent and extensive changes in the gallbladder were almost always accompanied by severe pain. Acute lesions were frequently not accompanied by febrile reaction or important elevation of the leukocyte count. Recent and extensive changes in the gallbladder were usually associated with the impaction of a stone in the cystic duct. On the other hand, it was found that the impaction of a stone in the common duct was not usually associated with extensive changes in the gallbladder.

Comparison of the gross and microscopic changes in the gallbladder in cases in which cholecystectomy was performed within two or three days after the impaction of a stone in the cystic duct made it clear that the primary lesions in the gallbladder were intramural edema, venous distention and intramural hemorrhage or intramural hematoma.

\* From the Department of Pathology, Cornell University Medical College.

\* The material on which this study is based was gathered from necropsy material at Hospital Santo Tomas, Panama, Republica de Panama, and from surgical material at the Brooklyn Hospital, Brooklyn.

\* Read before the New York Pathological Society, Nov. 12, 1925.

The fact that these circulatory changes were not usually attended by important febrile reaction and the absence of thromboses in the cystic vessels made it appear that the circulatory changes were not part of an acute inflammatory reaction but mechanical effects induced by the impaction of a stone in the duct. The veins and lymphatics of the gall-



Fig. 1.—Infarcted and infected gallbladder; recovery was made without peritonitis.

bladder are much more intimately incorporated in the cystic duct than is the cystic artery. The cystic artery is usually isolated and ligated separately. It follows, therefore, that impaction of a large stone in the cystic duct closes off the veins and lymphatics before the artery and causes intramural edema and venous distention. If the stone is

large enough and the interference with the lymph and venous return sufficient intramural hemorrhage or a condition analogous to infarction results.

The material available for study consisted of 403 cases in which cholecystectomy had been performed. The gross and microscopic specimens were carefully sorted, with the aid of the clinical histories, and arranged in the order of the acuteness of the processes observed. Of

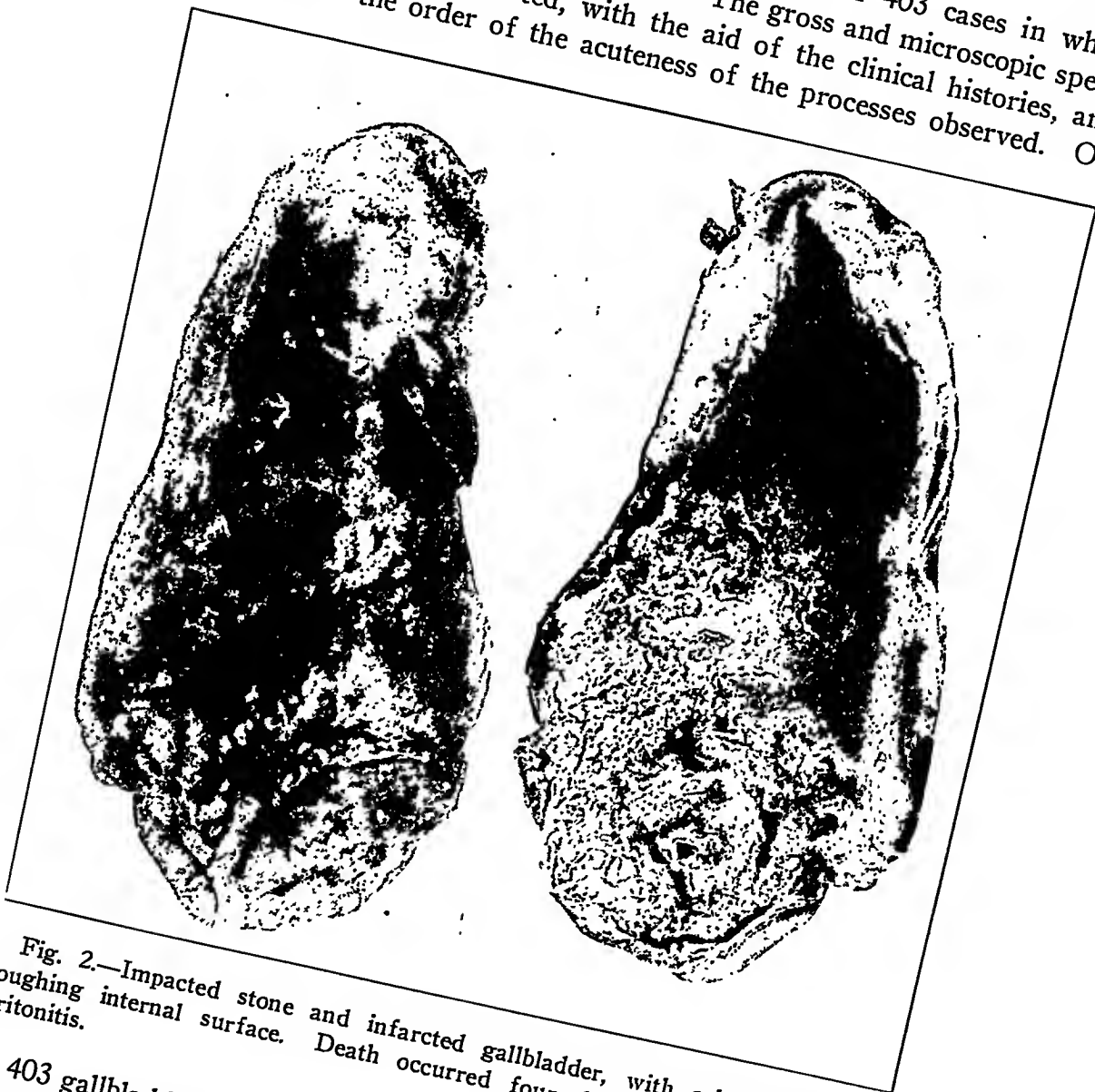


Fig. 2.—Impacted stone and infarcted gallbladder, with colon bacillus in sloughing internal surface. Death occurred four days after operation with peritonitis.

the 403 gallbladders, 188 contained stones. There were definite pathologic changes in 121; the remaining sixty-seven showed only a negligible degree of fibrosis or an atrophic thinning of the wall. In 215 gallbladders that did not contain stones, definite pathologic changes were found in nineteen. In some of the nineteen the clinical histories were very suggestive of the previous presence of stones and the changes were so similar to those in stonebearing gallbladders with pathologic changes



that it is possible that stones had been present but had been passed or were overlooked at operation. In these gallbladders the fact that the circulatory changes were entirely out of proportion to other evidences of inflammation made it appear that some other factor than infection was concerned in the production of the changes.

In reviewing this material ideas gathered from postmortem experience were of material assistance in the evaluation of some of the minor



Fig. 3.—Intramural hematoma—the hemorrhage follows two planes, subserous fat and submucous stroma; effect of stone impaction; area not infected.

changes observed in some surgical specimens. Particular attention was paid to the gallbladder and biliary tract in somewhat over 600 necropsies. The structure of the gallbladder can vary considerably in persons of different ages without being in any real sense pathologic. In obese subjects the subserous fat is commonly increased in amount. Slight fibrosis of the fibromuscular tunic, sclerosis of the subserous fat and augmentation of the cells of the submucous stroma have been frequently

observed in postmortem material in which they were clearly of no pathologic significance. Personal experience has taught that it is at times difficult to discriminate grossly between lymph nodes and sympathetic nerve ganglions and occasionally sympathetic nerve ganglions are excised for lymph nodes.



Fig. 4.—Effects of repeated episodes of stone impaction; cicatrized gallbladder with intramural edema and hematoma.

No changes were found in gallbladders that had not contained stones which could be regarded as infectious lesions. No lesions analogous to those commonly met with in acute inflammatory processes in the oviduct, appendix or urinary bladder were found in gallbladders without stones. The only definite change observed where the previous presence of stones

could be excluded was the so-called "strawberry gallbladder." It is difficult to understand just what significance is to be attached to this condition but it gives no evidence of being of an infectious origin.

Recent and mild effects of stone impaction were observed in eight specimens. The gallbladders were slightly distended, tense and salmon colored. Sections showed the effects of interference with the lymph and venous return from the gallbladder as there was coagulated edema fluid

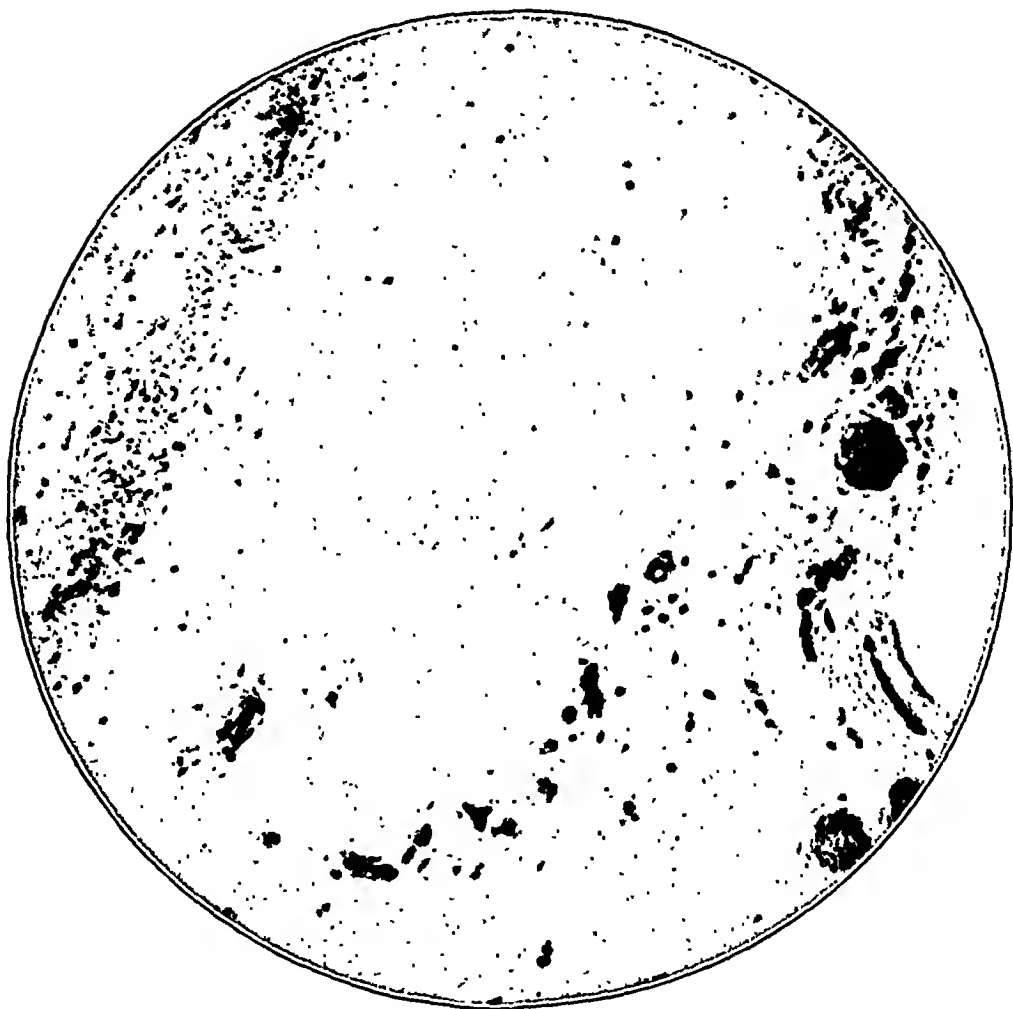


Fig. 5.—Early mechanical effect of edema of subserous fat.

in the intercellular spaces in all coats. The submucous is the most delicate coat and edema and venous distention were the most extensive in this location. The mucous membrane in these specimens was generally intact and unaltered except in small areas where it had been pushed off its backing by edema or by small hemorrhages.

In several specimens analogous but more extensive effects were observed. These gallbladders were distended, tense and bright red or

pinkish red, with splashes of darker red in the subserous fat. The contents were ordinarily pink stained bile. Histologically there was marked edema, venous distention and laceration of the subserous fat compartments and submucous stroma by the edema and hemorrhage. Submucous hemorrhages in particular produced extensive injury to the mucous membrane. In the earliest lesions found there was ample evidence of injury which would excite cellular reaction and cause cellular prolifera-

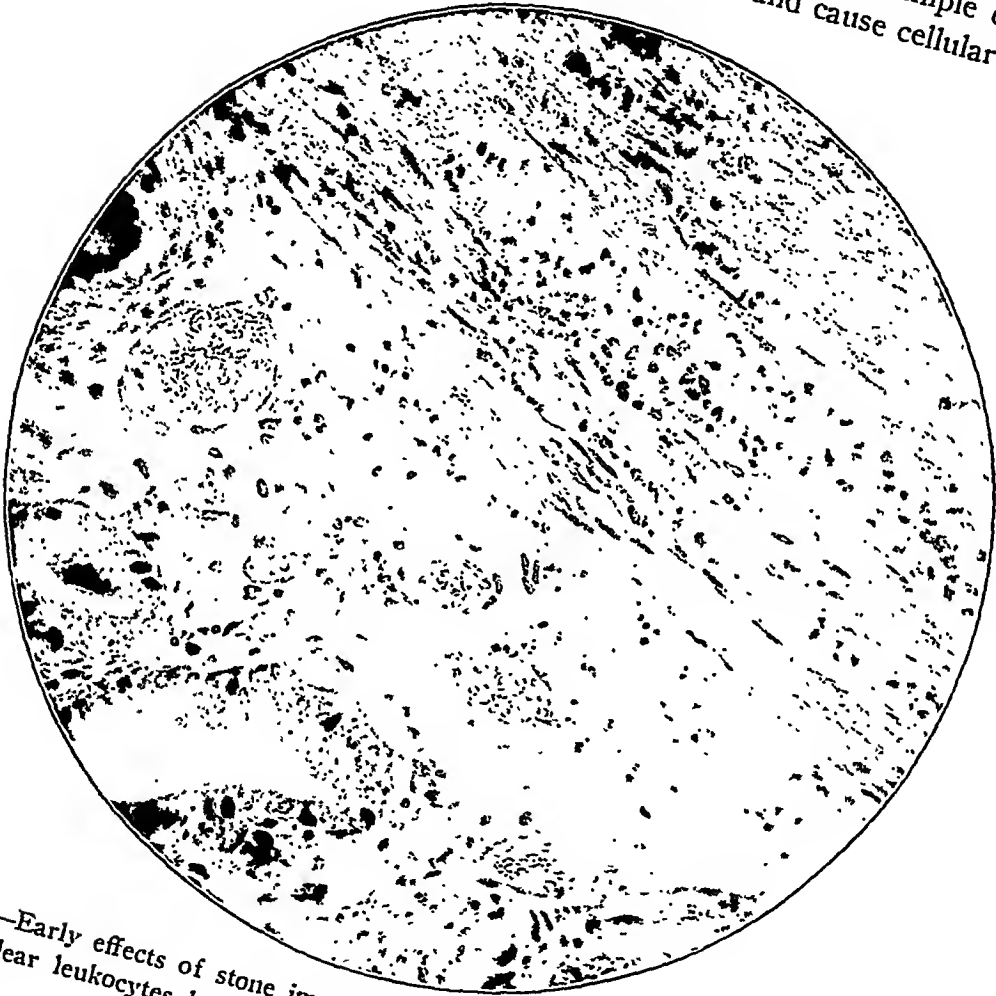


Fig. 6.—Early effects of stone impaction; intramural edema with a few polymorphonuclear leukocytes between stretched muscle bundles.

tion in the processes of repair. Organization of hemorrhage was observed to start soon and to proceed rapidly at first. The later processes of removal of necrotic tissue and replacement by scar tissue appear to take a long time. In two specimens in which the interval following the injury could be estimated with considerable accuracy, numbers of mitotic figures could be found in connective tissue cells of the subserous fat within forty-eight hours.

The most violent lesions observed were in cases in which the impaction of a stone resulted in a condition which has many features in common with hemorrhagic infarction. In these circumstances, the gallbladders were dark red to almost black and friable. In three cases the abdominal cavity contained pink stained fluid. The internal surfaces of the gallbladders presented various appearances, depending on the extent and duration of the process. They were blackish red and smooth or

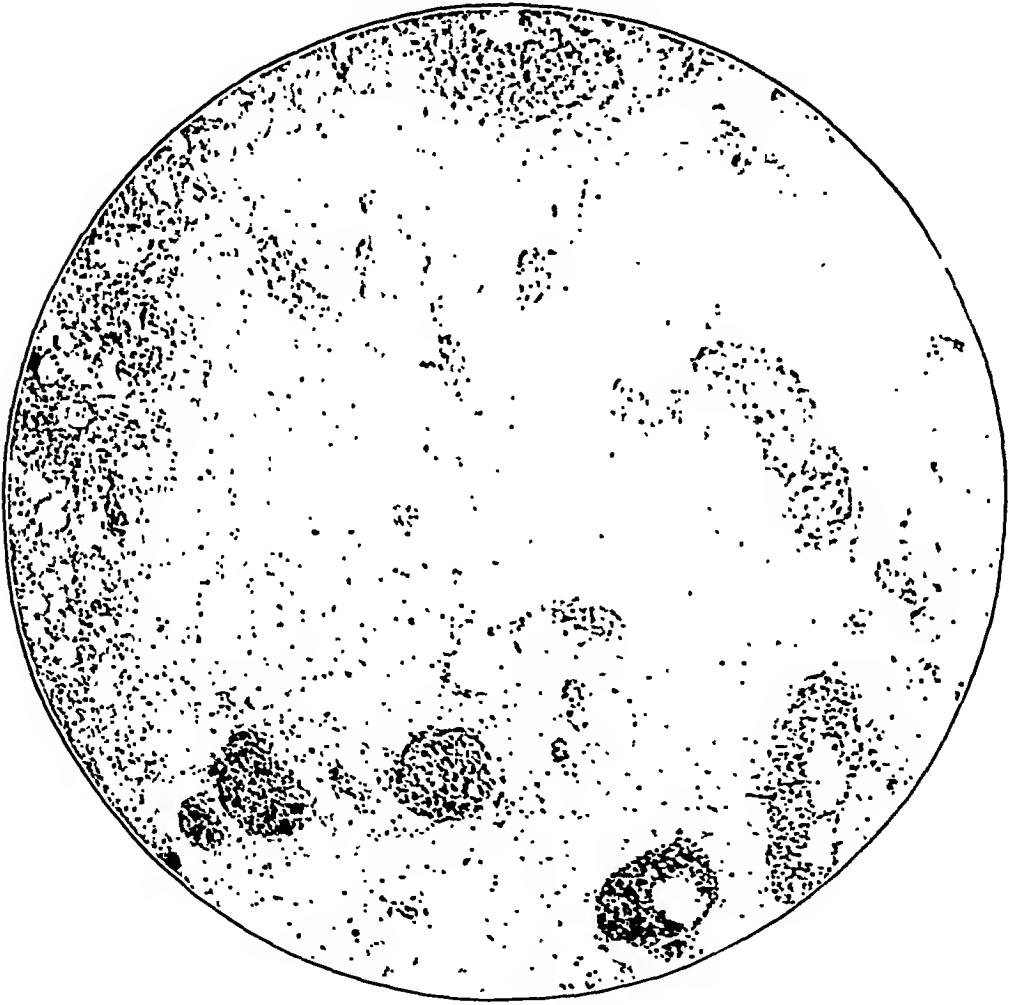


Fig. 7.—Edema and venous congestion in subserous fat associated with stone impaction; the vessels are held apart by coagulated serum.

shaggy with red or grayish red tags and strings of fibrin hanging from the internal surfaces. The contents were bloody fluid mixed with mucous and stones and grayish red or puriform material. Histologically the walls consisted of blood in various stages of disintegration and lacerated connective tissue elements of the wall. The mucous membrane was in most instances almost completely destroyed, but tags of quite normal appearing mucosa could usually be found free in the gallbladder

cavity or attached to edematous stroma. In areas in which the mucous membrane was destroyed there was sometimes a broad zone of blue staining mucous or serous material, beneath this a narrow stratum of leukocytes lying in a matrix of blue staining amorphous material, and beneath this edematous stroma or intramural hematoma. The leukocyte zone was peculiar in that the different varieties of leukocytes were present in about the same proportions as in blood and in some instances

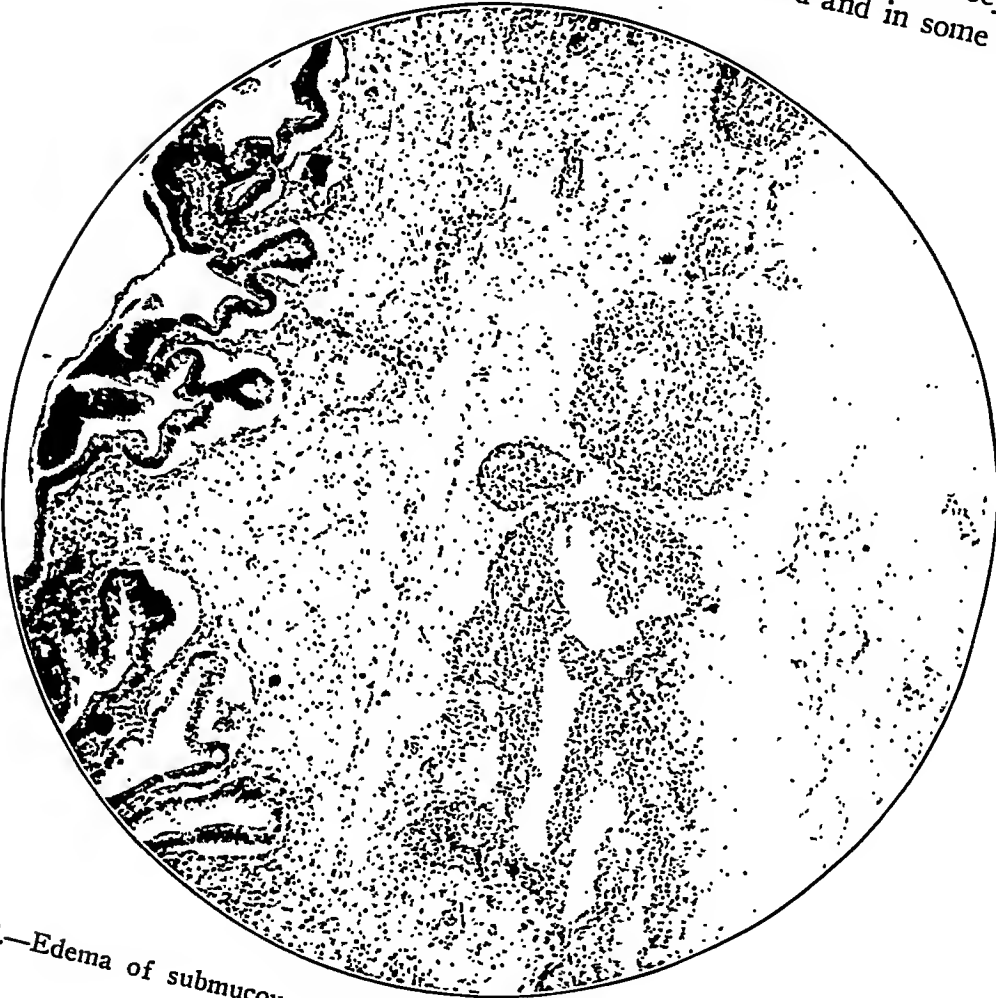


Fig. 8.—Edema of submucous stroma; epithelium detached by shrinkage in technic.

pale shadows of red blood corpuscles were still recognizable between them. The whole appearance was such as one would expect if a submucous hemorrhage had burst into the gallbladder cavity and some digestive ferment had dissolved everything but the leukocytes and a few resistant connective tissue fibers. Microscopic examination of the fluid in the gallbladders supported this view for it was ordinarily found that it contained very few cells of any description and was not pus.

The terminations of these circulatory lesions appear to be diverse. Fatal intra-abdominal hemorrhage has been reported where the gallbladder sloughed. Rupture of the gallbladder can either allow the stones to escape into the abdominal cavity, or a fistula forms with subsequent perforation of the intestine. Stones have been found at necropsy hanging in the omentum like so many grapes without any traces of peritonitis. In three instances in this material a large stone found its

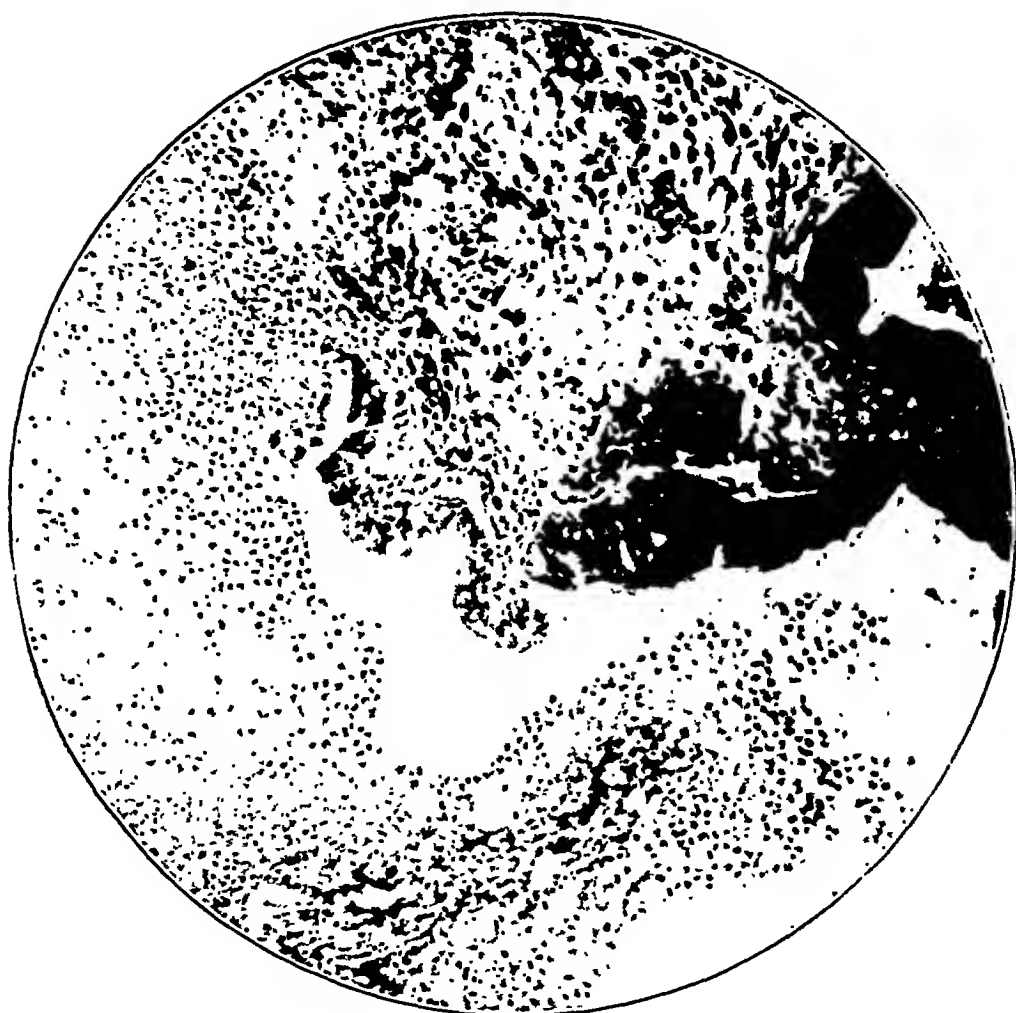


Fig. 9.—Infarcted and infected gallbladder resulting from stone impaction; coagulum in wall escaping into the lumen; colon bacillus and saphrophytic streptococcus.

way into the intestine and caused intestinal obstruction. Secondary infection from the duodenum can result in empyema of the gallbladder or in an intraperitoneal abscess. Neither of the latter conditions are often treated by cholecystectomy as the patients are ordinarily desperately ill by the time infection has occurred and drainage is all that is usually attempted. What is commonly referred to as empyema of the gallbladder would usually be described by some other term if the contents were

examined microscopically. I know of several instances in which stones were overlooked at the time of operation and were found at a secondary operation in a walled off abscess weeks or months later.

The various stages of repair of mechanical lesions and circulatory effects could be followed in cases in which repeated attacks of gallstone colic had preceded cholecystectomy and in cases in which a violent attack of gallstone colic had been allowed to subside before operation.

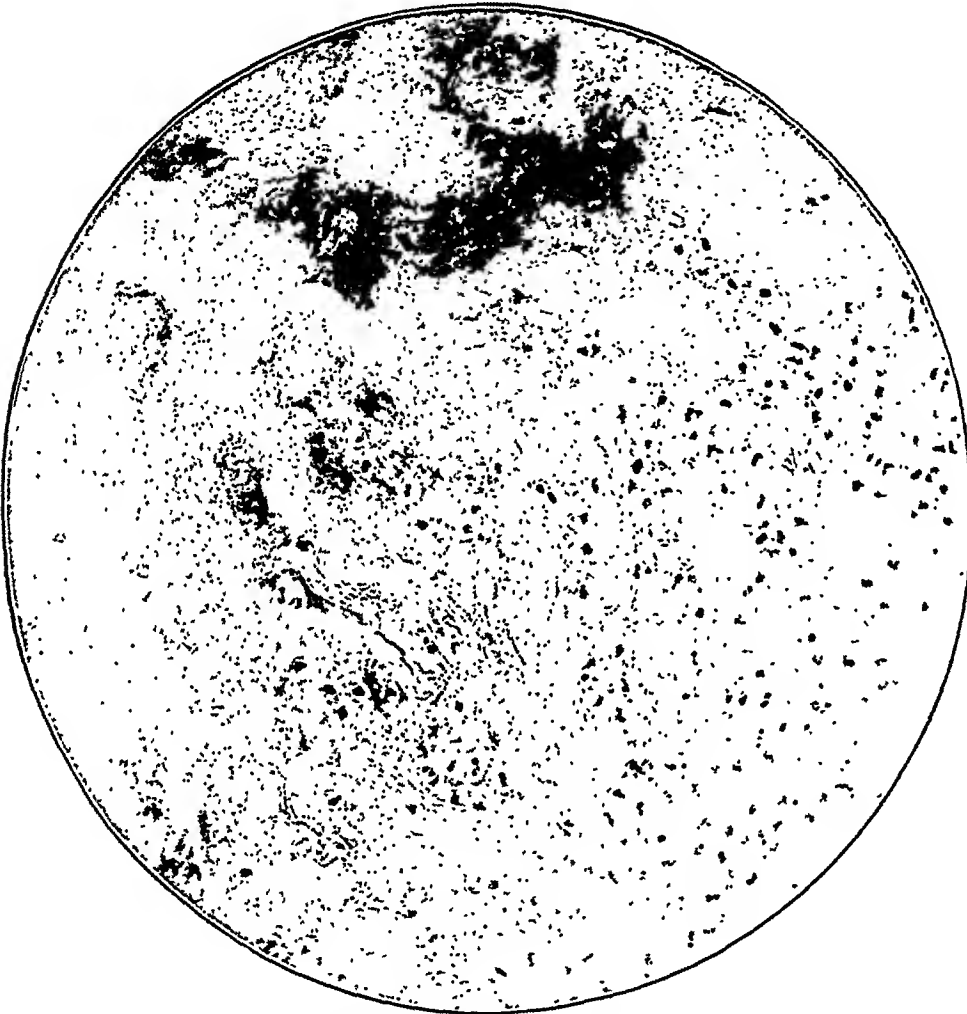


Fig. 10.—Completely infarcted area sloughing into the gallbladder cavity; bacteria are occasionally present in these areas.

Intramural edema and hematoma tend to be replaced by layers of scar tissue of different ages. Extensive thickening can result without any evidence of exudative inflammation and constitute a purely reparative process. The thickening in some instances assumed almost neoplastic proportions from the proliferation of interfascicular connective tissue cells. In several instances the gallbladder was a thick walled bag of scar tissue without a trace of submucous stroma or any residuum of inflammatory reaction.



It was reasoned that if the acute lesions of the gallbladder were primarily infectious, bacterial stains should show what particular microorganisms were responsible for their production. Thin paraffin sections of ninety-four gallbladders were stained with Giemsa's and Goodpasture's stains after fixation in Zenker's fluid. Twenty-four of the specimens treated in this way were from clinically acute cases and the

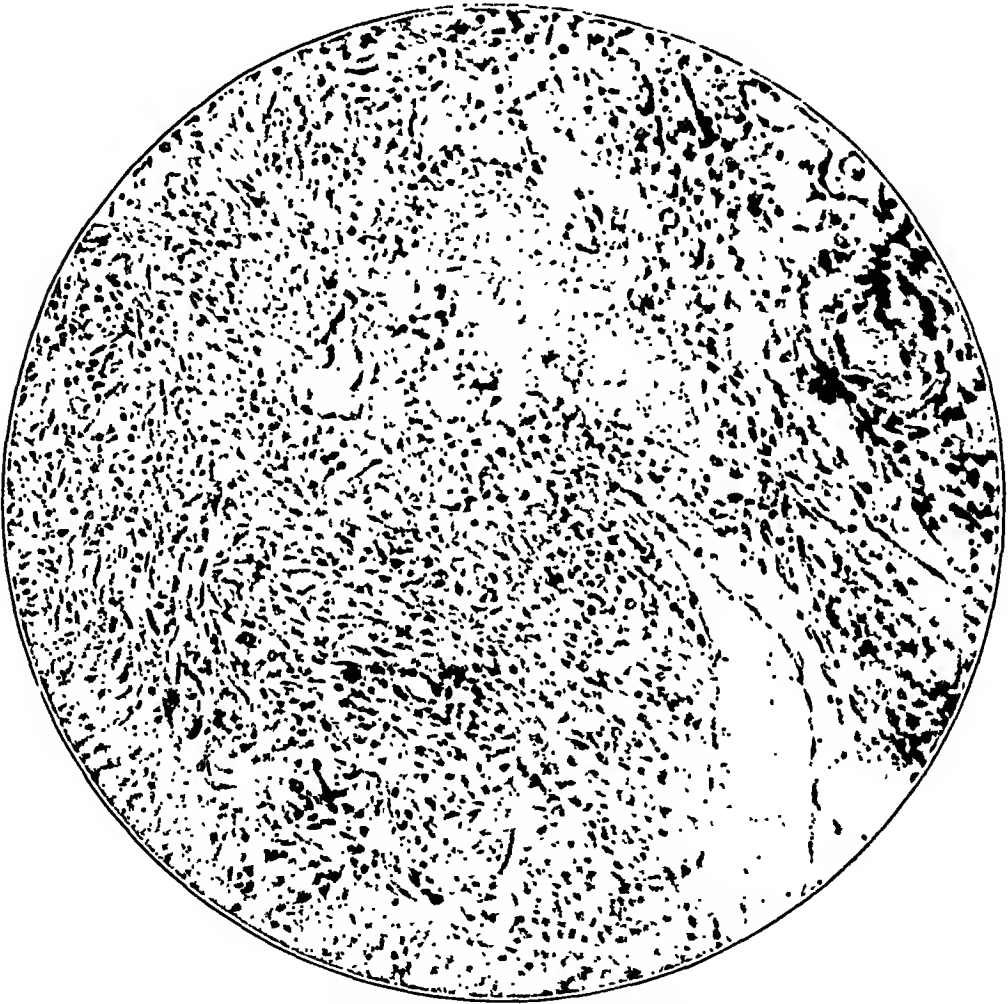


Fig. 11.—Repair in gallbladder wall nine days after acute crisis, showing edematous fibroblastic reaction.

lesions were recent. Colon bacilli and coarse gram-positive bacilli were found in the sloughing internal surfaces of four infarcted gallbladders. The lesions in these four cases were primarily intramural circulatory lesions and from the location in which the bacteria were found it is doubtful if they were the cause of the lesions. Bacteria could not be found in the sections of the remaining seventy specimens.

## CONCLUSIONS

Recognition of mechanical and circulatory effects is important because they are evidence of cholelithiasis and of entrance of stones in the duct system.

It has not been possible to demonstrate, in this series of cases, lesions that were primarily of bacterial origin.

Other factors than bacterial infection are necessary for the explanation of some of the commonly observed lesions of the gallbladder.

If primarily infectious lesions of the gallbladder occur they must be uncommon.

Lesions of the gallbladder should be regarded as bacterial in origin after demonstration of the causative organism in the lesion a fair number of times.

The terms acute, subacute and chronic cholecystitis are undesirable because they carry the implication of infectious origin and cannot be correlated with clinical conditions. Pathologic states of the gallbladder should be described in morphologic terms as edema, edema and hemorrhage, hematoma, partial infarction, complete infarction, edematous cicatrix and cicatrix.

The presence of gallstones in a gallbladder is not necessarily accompanied by pathologic changes in the gallbladder. In this series of cases approximately two thirds of the stone bearing gallbladders had definite pathologic changes.

# THE PATHOGENESIS OF BILIARY CALCULI\*

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The conception of disease of the gallbladder is undergoing an interesting change. It now seems that often the early phenomena of disease of the gallbladder are concerned with metabolic changes, rather than bacterial. The study of the formation of gallstones may, therefore, enhance the study of metabolic diseases, as the two appear to be concerned with much the same phenomena.

## TYPES OF GALLSTONES

If the classification of gallstones is based on their essential constituents, there are probably only two distinct types, the cholesterin stone and the bilirubin calcium stone. All other types of stones can be grouped with these two. A review of the essential features of each of the gross types of stones may simplify our classification and facilitate the study of the pathogenesis of biliary calculi.

*Cholesterin Stone.*—Cholesterin stones have been classified in three groups by the pathologist: (1) the pure cholesterin stone, which contains free or conglomerate cholesterin crystals; (2) the radiate cholesterin stone, which is essentially a cholesterin-rich stone, composed of cholesterin crystals arranged in a radiate manner about a nucleus, and containing little other substance, and (3) the "common stone," which has been classified separately but is essentially a cholesterin stone, composed of varying proportions of cholesterin and bile pigment, with fractional amounts of various metals such as sodium, potassium, calcium, magnesium, iron, copper, sulphur, phosphate and zinc.

*Bilirubin Calcium Stone.*—This stone has been classified separately and probably rightly so. It is usually, but not necessarily, of intra-hepatic origin, as multiple stones have occasionally been found in the lumen of the gallbladder alone. The stones are small, black and spicular, and are composed of bile pigment mixed with mucus and traces of calcium, and rarely contain cholesterol. These are the so-called "coral tree stones" that sometimes form casts of the hepatic ducts.

The calcium carbonate stone is usually given a separate classification, but I group it with the bilirubin calcium stone, as it also contains little cholesterol. It is a noninflammatory stone, rare in man, but common in animals.

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\* Read before the American Association of Pathologists and Bacteriologists, Washington, D.C., May, 1925.

THEORIES OF STONE FORMATION

*Stasis Theory.*—Stasis of bile has long been considered a primary factor in the etiology of stones. This condition has been attributed to the inactivity of a sedentary life, with decreased muscular movements of the diaphragm, abdominal wall and enclosed organs. In this connection the rarity of stones in animals and their comparative frequency in man is interesting. Fox<sup>1</sup> has reported only six animals affected in an extensive zoo series, and in 9,000 cattle that I examined in an abattoir only 0.4 per cent had gallstones, whereas 21 per cent of 600 consecutive necropsies at the Mayo Clinic revealed biliary calculi.

The German school emphasizes the effect of constriction of the biliary duct with the resultant stasis of the bile. This is produced by tight clothing and by posture, and they therefore consider corsets, viscerop-tosis and the asthenic upright habitus of man as frequent predisposing factors in gallstone formation. However, many cases have been found in which undoubted stasis of gallbladder bile has occurred, even in the presence of marked infection, with no indications of gallstone formation.

*Infection Theory.*—The infective theory of gallstone formation was introduced by Gallipe<sup>2</sup> in 1886, was affirmed by Naunyn<sup>3</sup> in 1892, and today biliary infection is most widely accepted as an essential factor in stone formation. Indeed, Aschoff and Bacmeister<sup>4</sup> regard biliary infection as the cause of all gallstones, with the possible exception of the rare pure cholesterin stone.

Nevertheless, this theory is denied by many, and numerous workers have found gallstones, especially cholesterin-rich stones, when there has been no gross evidence of inflammatory changes in the wall of the gallbladder. The surgeon in particular has seen calculi in gallbladders with thin walls devoid of any of the usual gross stigmas of inflammatory changes. He has frequently had this experience in performing chole-

1. Fox, Herbert: *Diseases in Captive Wild Mammals and Birds; Incidence, Description, Comparison*, Philadelphia, J. B. Lippincott Company, 1923.

2. Gallipe, quoted by Rothschild, M. A., and Wilensky, A. O.: *Studies in Cholelithiasis: I. The Disturbances of the Cholesterin Metabolism as a Factor in Gallstone Formation*, Am. J. M. Sc. 156:239-247, 1918; II. *The Clinical Relationships of the Cholesterinemia to the Pathological Process*, ibid. 156:404-414, 1918; III. *The Immediate Effect of the Various Types of Operations upon the Cholesterinemia*, ibid. 156:564-574, 1918; IV. *The Late and Permanent Results of the Various Types of Operation on the Biliary Passages with Special Reference to the Cholesterol Metabolism*, ibid. 168:65-77 (July) 1924.

3. Naunyn, B.: *Klinik der Cholelithiasis*, Leipzig, F. C. W. Vogel, 1892; *Klinik der Cholelithiasis*, Leipzig, F. C. W. Vogel, 1909; *Die Cholelithiasis*, Jena, Gustav Fischer, 1921; *Die Gallensteine, ihre Entstehung und ihr Bau*, Mitt. a. d. Grenzgeb. d. Med. u. Chir. 33:1-54, 1921.

4. Aschoff, Ludwig; and Bacmeister, Adolf: *Die Cholelithiasis*, Jena, Gustav Fischer, 1909.

quently thin walled and comparatively free from inflammatory changes. But with increasing proportions of bile pigment in the stones inflammatory changes in the wall of the gallbladder became more marked. In the cases of dark "common" stones inflammatory changes in the wall of the gallbladder were invariably present, in contrast to the cases of

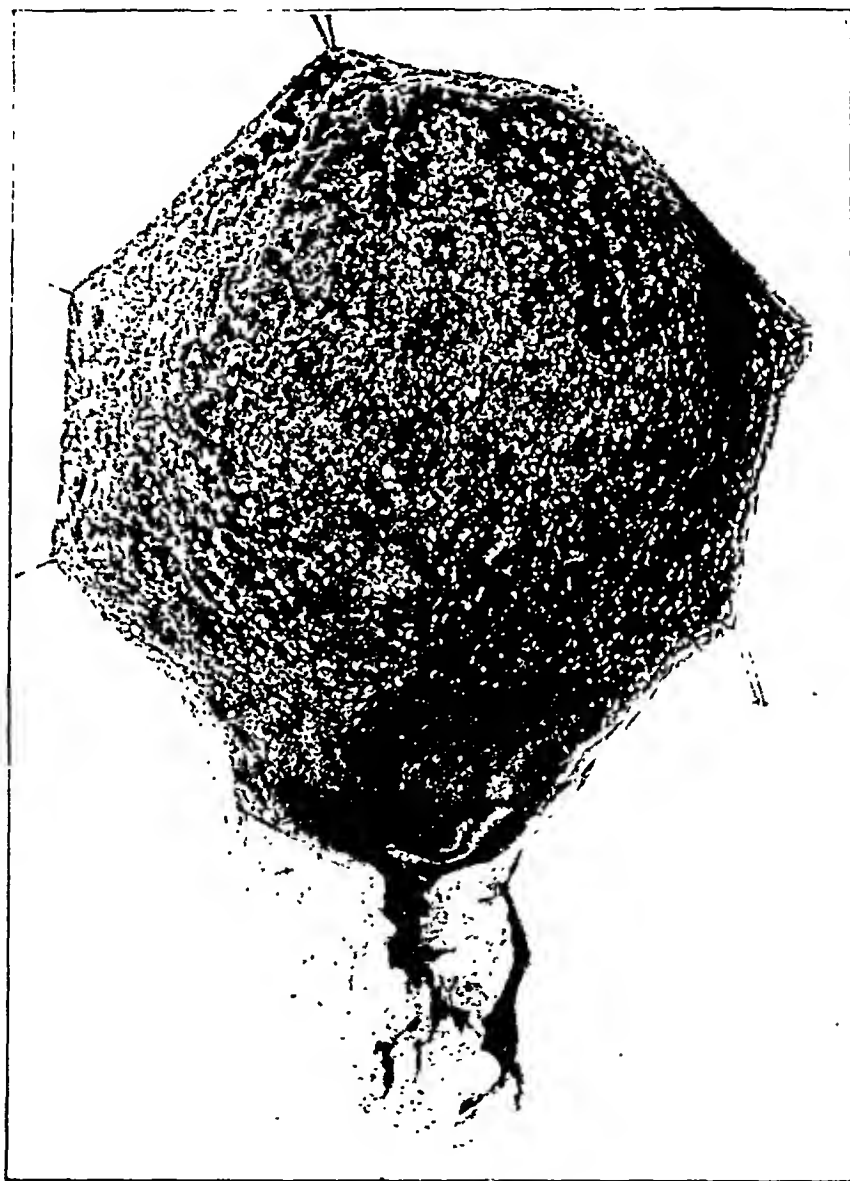


Fig. 2.—Cholesterosis of the gallbladder.

cholesterin stones. This observation suggests that the deposition of bile pigment probably has some relation to inflammatory changes in the wall of the gallbladder, but that cholesterolin precipitation occurs independently of such pathologic change.

Gallstones in the new-born have been reported in nine cases. These stones were formed in the fetus, and were therefore presumably not of

cystectomy for cholelithiasis in cases in which he has been able readily to palpate calculi within the gallbladder in situ. Indeed, the wall is sometimes so thin that it is quite transparent, in many cases not more than 2 mm. thick, which is considered the normal thickness by most anatomists.

The experience of the pathologist has paralleled that of the surgeon. In a series of 612 gallbladders which were removed at necropsy,

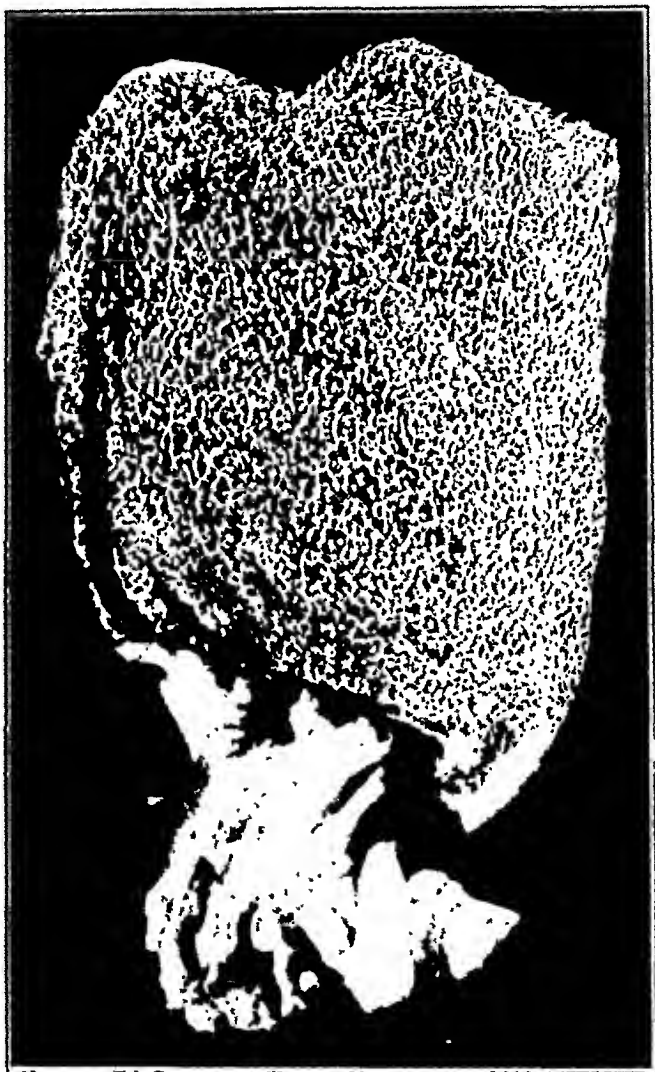


Fig. 1.—Cholesterosis of the gallbladder.

although stones were found in many, I found four in which the presence of single or multiple stones was not associated with gross or microscopic evidence of inflammatory changes. In such cases the type of gallstone is significant, for it is usually in such normal appearing gallbladders that the pure cholesterol or cholesterol-rich stone is found. In the necropsy series studied this fact was striking. The gallbladders containing cholesterol-rich stones were fre-

inflammatory origin.<sup>5</sup> Also, calculi found in five nurslings have been reported, and these, likewise, were probably noninflammatory in origin. Gallstones have been found in infants and children in increasing numbers as age advances, but the incidence of gallbladder infection likewise increases with age, although it remains remarkably low until adolescence.

Pure cholesterin or cholesterin-rich stones only are found in cases of cholelithiasis without significant inflammatory changes in the gallbladder.



Fig. 3.—Cholesterin polyp of gallbladder containing bile pigment.

The large incidence of gallstones associated with gross evidence of cholesterin disturbance in the wall of the gallbladder ("cholesterosis") is well known to both surgeon and pathologist.<sup>6</sup> In my post-mortem study, in 19 per cent of the gallstone cases there were cholesterin stones and in addition gross cholesterin deposits in the wall of

5. Mentzer, S. H.: A Clinical and Pathologic Study of Cholecystitis and Cholelithiasis, *Surg. Gynec. Obst.* 42:782 (June) 1926.

6. Mentzer, S. H.: Cholesterosis of the Gallbladder, *Am. J. Path.* 1:383-388 (July) 1925.

the gallbladder (figs. 1 and 2). It is significant that the gallstones in cases of cholesterosis of the gallbladder are usually cholesterin-rich stones (cholesterin crystals, radiate cholesterin stones, mulberry stones, gooseberry stones, jack stones or common stones rich in cholesterin). MacCarty,<sup>7</sup> in his descriptions of the "strawberry" gallbladder, that is, cholesterosis, has noted that the inflammatory changes are often meager. The papillomatous gallbladder, which is but another manifestation of



Fig. 4.—Marked papillomatosa of the gallbladder.

this cholesterin disturbance, is likewise often devoid of any macroscopic or significant microscopic inflammatory change. I am convinced that papillomas play a prominent part in the formation of cholesterin stones, as each papilloma is a polypoid projection of mucous membrane and

7. MacCarty, W. C.: The Pathology of the Gallbladder and Some Associated Lesions, *Ann. Surg.* 51:651-669, 1910; The Frequency of Strawberry Gallbladder, *Ann. Surg.* 69:131-134 (Feb.) 1919. MacCarty, W. C., and Corkery, J. R.: Early Lesions in the Gallbladder, *Am. J. M. Sc.* 159:646-653 (May) 1920.



stroma, laden with cholesterin esters (figs. 3 and 4). Boyd<sup>8</sup> and Stewart<sup>9</sup> believe that these cholesterin-laden polypi break off and lie free in the cavity of the gallbladder, forming potential nuclei for the formation of biliary calculi (fig. 5). I have sectioned numerous "mulberry" gallstones and dissolved out the cholesterin contained within them, noting that the organic structure closely resembled that of the polypi in the papillomatous gallbladder. Naunyn and Aoyama<sup>10</sup> have also noted the organic framework of gallstones. It would seem reasonable that portions of the mucous membrane of the gallbladder laden with cholesterol esters play a significant part in the formation of cholesterin stones by furnishing ideal nuclei for precipitation of bile constituents. However this may be, the pathologist has often seen a "strawberry" gallbladder so thin walled and devoid of gross inflammatory change

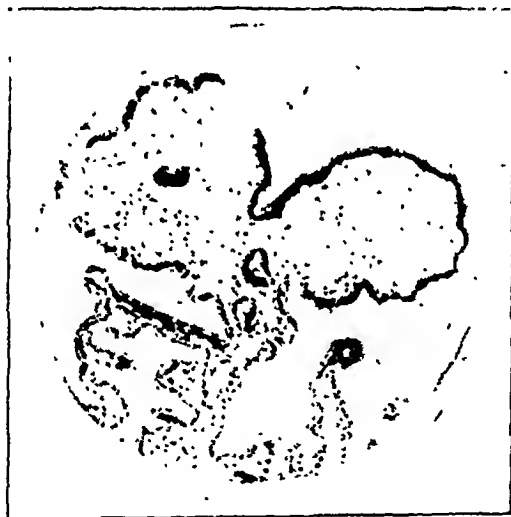


Fig. 5.—Cholesterin laden polyp of the gallbladder showing slender pedicle.

that the yellow rugae of the mucosa could be seen through the serosal surface of the organ. The presence of gallstones in such cases is not unusual, and the comparative absence of microscopic inflammatory changes in the wall of the gallbladder is of the utmost importance.

That bacteria are found in the wall of the gallbladder in most cases of gallstones, however, is an undisputed fact. Moreover, gallstones have been produced experimentally in animals by massive intra-

8. Boyd, William: Gallbladder Problems, Canadian M. A. J. **12**:689-693 (Oct.) 1922; Studies in Gallbladder Pathology, Brit. J. Surg. **10**:337-356 (Jan.) 1923.

9. Stewart, M. J.: Xanthoma and Xanthosis, Brit. M. J. **2**:893-896 (Nov. 15) 1924.

10. Aoyama, T.: Zur Frage der Cholelithiasis, Beitr. z. path. Anat. u. z. allg. Path. **57**:169-182, 1914.

venous injections of organisms. Fütterer,<sup>11</sup> Cotton,<sup>12</sup> Wechselbaum,<sup>13</sup> Kraus,<sup>14</sup> Meyer, Neilson and Feusier,<sup>15</sup> and Rosenow<sup>16</sup> have demonstrated the localization of bacteria, so injected, in the wall of the gallbladder. In such instances, however, bacterial emboli occur, producing obstruction of the arterial flow in the villi of the mucosa of the gallbladder and, thus, necrosis of the terminal villi, with resultant sloughing of the tissue. That this is not the usual method of gallstone formation is evident from microscopic studies of the wall of the gallbladder. It seems much more likely that the inflammatory changes in the mucosa and stroma of the diseased organ prevent the passage of water and cholesterol through it, and so disturb the chemical equilibrium of the gallbladder bile.

Contrary to the usual conception of the origin of bilirubin calcium stones is that of Rous and co-workers,<sup>17</sup> who found floccules of bilirubin and calcium carbonate deposited on the glass tubing, in experimental work on dogs with no evidence of inflammatory change in the bile ducts.

*Nucleus Theory.*—In my examination of several thousand gallstones, a nucleus of some sort was invariably found, and therefore appears to be an important adjunct in stone formation. A nucleus may be a mechanical necessity for the precipitation of the constituents of a stone, or it may be but an incident in its formation. No gallstone is without a grossly demonstrable nucleus. A foreign substance, introduced into the cavity of the gallbladder, will not, alone, cause a stone to form. Cholesterin crystals occur singly, and even in large quantities in the gallbladder without forming stones, a phenomenon that Rous has duplicated experimentally as just described.

The nuclei of gallstones have often been very interesting. For instance, the literature contains twenty-three instances in which the

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11. Fütterer, quoted by Singer, Gustav: *Die Gallensteinkrankheit*, Berlin, Urban and Schwarzenberg, 1923.

12. Cotton, quoted by Singer, (footnote 11).

13. Wechselbaum, quoted by Singer (footnote 11).

14. Kraus, Ignaz: *Beiträge zur Pathologie und Therapie der Gallensteinkrankheit*, Berlin, A. Hirschwald, 1891.

15. Meyer, K. F.; Neilson, N. M., and Feusier, M. L.: *Mechanism of Gallbladder Infections in Laboratory Animals*, *J. Infect. Dis.* **28**:456-509; 510-542 (May-June) 1921.

16. Rosenow, E. C.: *The Etiology of Cholecystitis and Gallstones, and Their Production by the Intravenous Injection of Bacteria*, *J. Infect. Dis.* **19**:527-556 (Oct.) 1916.

17. Rous, Peyton; and McMaster, P. D.: *The Concentrating Activity of the Gallbladder*, *J. Exper. Med.* **34**:47-73 (July) 1921; *Physiological Causes for the Varied Character of Stasis Bile*, *ibid.* **34**:75-95 (July) 1921. Rous, Peyton; McMaster, P. D., and Broun, C. O.: *Studies in Total Bile; Effects of Operation, Exercise, Hot Weather, Relief of Obstruction, Intercurrent Disease and Other Normal and Pathological Influences*, *J. Exper. Med.* **37**:395-420 (March) 1923.

roundworm *Ascaris* formed the nucleus of a gallstone. DeGorce<sup>18</sup> reports a case of forty cholesterol stones, in each of which an *Ascaris* was found, and Novack<sup>19</sup> reports a huge stone, weighing 200 Gm. containing an *Ascaris* in its center. Lobstein<sup>20</sup> has reported a roundworm (*Ascaris*?) in a gallstone, Bouisson<sup>21</sup> a portion of a distoma hepaticum, and Singer<sup>22</sup> has cultured plasmodia from the center of gallstones.

The usual nuclei, however, are masses of bile pigment, so-called "bile thrombi" of Naunyn. Rovsing<sup>23</sup> believes that most of these masses are bilirubin calcium stones that have wandered into the gallbladder from the intrahepatic ducts. Such nuclei as masses of bacteria, mucus plugs, blood coagulum, epithelial cells or cholesterol crystals have been found, however, and occasionally reports of solid foreign particles, such as portions of sutures or needles and even "grape seeds," have been reported in the literature. Nor is it rare to discover that a gallstone of one type has formed the nucleus of a totally different type of stone.

*Hypercholesterolemia Theory.*—In 1909 Aschoff and Bacmeister<sup>4</sup> introduced the theory that dysfunction of the cholesterol metabolism in the body is a contributing factor in the formation of gallstones. Their views have since won wide acceptance, and there are ever increasing data that bear out their contentions. Aschoff<sup>24</sup> still insists that stasis of bile, gallbladder infection and hypercholesterolemia are necessary for the production of gallstones. Wilensky,<sup>25</sup> the most ardent proponent of the hypercholesterol theory, likewise insists that infection is associated with an increase of cholesterol in the blood and bile in the pathogenesis of biliary calculi.

On the other hand, Rothschild and Wilensky,<sup>26</sup> and Rovsing<sup>23</sup> believe that a saturation of the gallbladder bile with cholesterol alone will precipitate stones, and Dewey<sup>27</sup> has produced gallstones in animals

18. DeGorce, quoted by Butt, A. P.: Round Worm (*Ascaris Lumbricoides*) in the Gallbladder, Surg. Gynec. Obst. 35:215-216 (Aug.) 1922.

19. Novack, quoted by Singer (footnote 11).

20. Lobstein: Report of a Surgically Treated Case of Hemorrhage of Gallbladder which Endangered Life, Gyógyászat, 1923, p. 286.

21. Bouisson, quoted by Naunyn (footnote 3, first reference).

22. Singer (footnote 11).

23. Rovsing, T.: Gallstones, Cause, Not Result of Infection, Acta chir. Scandinav. 56:103-155; 207-272, 1923.

24. Aschoff, Ludwig: Lectures on Pathology, New York, Paul B. Hoeber, 1924.

25. Wilensky, A. O.: Hypercholesterolemia, Surg. Gynec. Obst. 38:163-170 (Feb.) 1924.

26. Rothschild and Wilensky (footnote 2).

27. Dewey, Kaethe: Experimental Hypercholesterolemia, Arch. Int. Med. 17:757-785 (June) 1916.

by feeding an excessive amount of fat. However, an excess of cholesterol in the bile cannot be necessary in the formation of all types of gallstone, for the bilirubin calcium stone is virtually without any cholesterol in its make-up.

Cholesterin was first noted in gallstones by Conradi<sup>28</sup> in 1775. Since then it has been observed that most gallstones contain considerable cholesterol, many being reported 95 per cent or more "pure cholesterol" by the Bloor determinations. Hypercholesterolemia in association with gallstones has been observed by Wilensky,<sup>25</sup> Rothschild and others.<sup>29</sup> In 200 determinations of the blood cholesterol in cases of gallbladder disease, compared with gallbladders proved "negative" at operation, I also found a relative increase in the blood lipoids. There is, of course, much variation in the cholesterol content of the blood, and although cholesterol values may be low even in the presence of gallstones, the average cholesterol content for a long period of observation will be high.

Huchard,<sup>30</sup> in 1882, first noted the relation of pregnancy to gallbladder disease, and his observations have been amply verified since. Osler<sup>31</sup> stated that 90 per cent of the women with gallstones had borne children, and others have given almost equally high estimates. In a recent postmortem study,<sup>5</sup> I found that 62 per cent of the women who had never borne children had gross gallbladder disease, whereas 77 per cent of the women who had been pregnant were so afflicted. Numerous workers have noted the hypercholesterolemia of pregnancy and the period immediately following parturition, and the well known association of gallbladder symptoms at these times is of suggestive value. In fact, many patients with gallbladder disease date the onset of their first symptoms to the latter months of pregnancy or the period immediately following. That there is a connection between this metabolic cholesterol disturbance of pregnancy and gallbladder disease is strongly supported.

That the metabolic fat disturbance in obesity is likewise associated with gallbladder disease, and especially stone formation, is suggested by necropsy statistics. In a postmortem study of patients weighing over 220 pounds (99.7 Kg.), 90 per cent had gallbladder disease, whereas only 30 per cent of the adult patients weighing 110 pounds (49.9 Kg.) or less had diseased gallbladders.<sup>6</sup>

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28. Conradi, quoted by Boyd (footnote 8, second reference).

29. Rothschild, M. A., and Rosenthal, N.: The Dietetic Management of Hypercholesterinemia in Cases of Cholelithiasis, *Am. J. M. Sc.* **152**:394-403 (Sept.) 1916.

30. Huchard, quoted by Schrager, V. L.: Clinical Observations on the Etiology of Gallstones in Women, *Surg. Gynec. Obst.* **38**:344-347 (March) 1924.

31. Osler, William: *Modern Medicine, Its Theory and Practice*. Philadelphia, Lea and Febiger, 1913-1915.

In this connection, it is interesting, too, that the morbidity of gallbladder disease varies quite remarkably with its geographic distribution. Americans apparently have a higher percentage of gallbladder disease than any other nationality, the postmortem records indicating that about 15 per cent of the adult population have biliary calculi. European statistics likewise give relatively high figures, the incidence from the average necropsy series being 10 per cent, whereas only 3 per cent of the Japanese women have stones<sup>32</sup> and 0.1 per cent of the natives of Java.<sup>33</sup> Lick<sup>34</sup> comments on the rarity of the cases of gallstones among the natives of Africa. It seems apparent that the low fat values of the food intake of these peoples is concerned with the low lipid content of the blood and bile, which is an inhibitory factor in the formation of the cholesterol "common" stone. Especially significant are these figures, when one recalls that gallstones have been produced experimentally in animals simply by excessive fat feeding.

In 1887 Bristowe<sup>35</sup> suggested that the mucosa of the gallbladder could excrete cholesterol, and Adami<sup>36</sup> and Herter<sup>37</sup> have concurred in this opinion. Recently Dewey,<sup>37</sup> Meyer,<sup>16</sup> Starling,<sup>38</sup> Boyd,<sup>8</sup> Grigaut<sup>39</sup> and Sweet<sup>40</sup> have ventured the opinion that the gallbladder mucosa might absorb cholesterol. I have been induced to agree with the latter by experimental work on dogs, in which lipoidal particles were found passing from the lumen of the gallbladder through the gallbladder wall and into the blood stream<sup>6</sup> (fig. 6).

From these data it seems likely that the prompt passage of lipoidal fat (cholesterol) is sometimes disturbed, with the resultant accumulation of cholesterol in the gallbladder wall, producing the pathologic picture of cholesterosis (that is, the "strawberry" and "papillomatous" gallbladders). When this passage of cholesterol through the gallbladder

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32. Mayaki, quoted by Singer (footnote 11).

33. De Langen, C. D., quoted by Henes, Edwin: Gallstones: Their Basal Etiology, Wisconsin M. J. 20:220-225, 1922.

34. Lick, quoted by McGuire, Stuart: Opinions on Various Questions in Gallbladder Surgery Based on 1,000 Operations, Virginia M. Month. 50:688-692 (Jan.) 1924.

35. Bristowe, quoted by Naunyn (footnote 3).

36. Adami, J. C.: On Gallstones and More Particularly Upon Their Cholesterin Constituents, West Canada M. J. 3:1-17, 1909. Adami, J. G., and Nicholls, A. G.: Principles of Pathology, Philadelphia, Lea and Febiger, 1909.

37. Herter, C. A.: The Etiology and Chemical Pathology of Gallstones, Tr. Cong. Am. Phys. & Surg. 6:158-194, 1903.

38. Starling, E. H.: The Principles of Human Physiology, Philadelphia, Lea and Febiger, 1915.

39. Grigaut, A.: Le cycle de la cholesterinémie, Paris, 1913.

40. Sweet, J. E.: The Gallbladder: Its Past, Present and Future, Internat. Clin. 1:187-226 (March) 1924.

wall is interfered with, there is a resultant accumulation of cholesterol in the gallbladder bile. This may reach the stage of supersaturation, or it at least disturbs the colloidal balance holding the cholesterol and bile salts in solution, with the consequent precipitation of these substances.

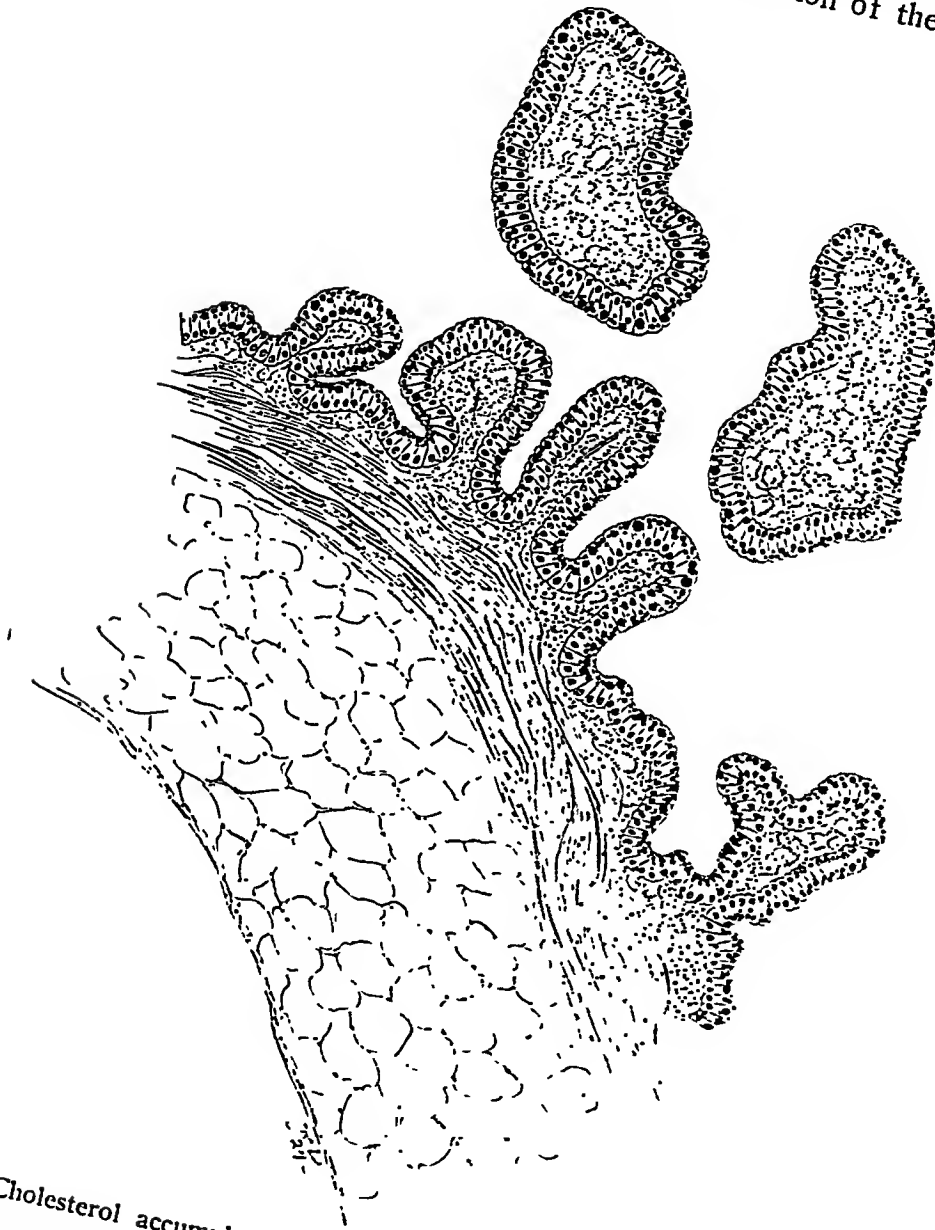


Fig. 6.—Cholesterol accumulation in epithelial cells of the gallbladder wall.

*Lichtwitz Theory.*—Of great interest is the Lichtwitz<sup>41</sup> theory of gallstone formation published in 1907, according to which bile is a colloid held in suspension by ions of like charges. With a change in the

41. Lichtwitz, L.: Experimentelle Untersuchungen über die Bildung von Niederschlägen in der Galle, *Deutsches Arch. f. klin. Med.* 92:103-108, 1907.

acid base reaction of the bile, these charges are altered, resulting in a precipitation of cholesterol. It is probable that the bile salts hold the cholesterol in suspension and that with a change in these salts, and a consequent variation in the acidity of gallbladder bile, this equilibrium is disturbed. The cholesterol content of the bile varies greatly from hour to hour, and it seems quite likely that the bile salt content likewise varies. The conditions, therefore, for such alteration of charges in the cholesterol ions are present; thus, the theory becomes a fascinating one, though difficult to prove.

The experimental work of Oliver<sup>42</sup> is in accord with this theory. Oliver demonstrated that bile in which gallstones had formed would be

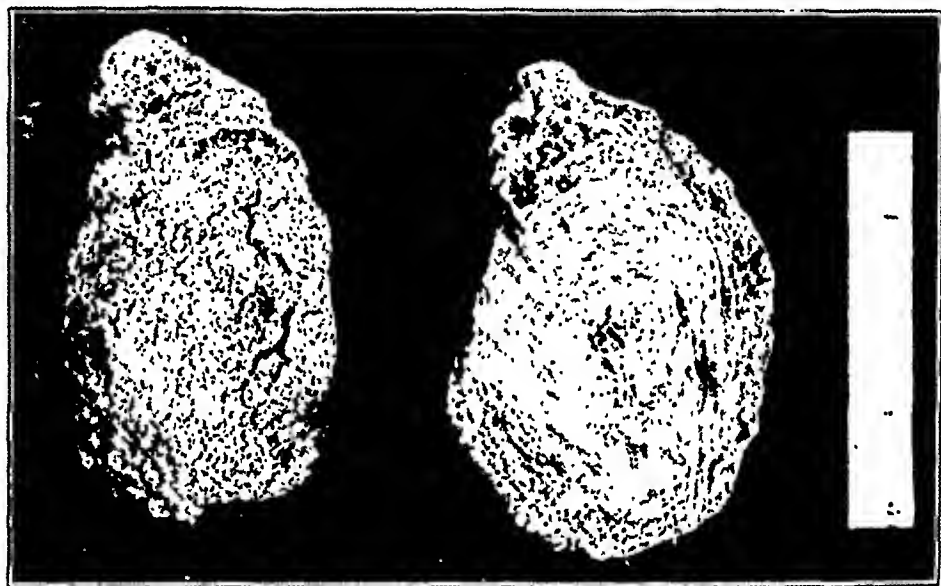


Fig. 7.—Small cholesterol stone, with massive precipitation of cholesterol material about it, completely filling the cavity of the gallbladder.

precipitated in layers if left in a test-tube for a number of hours, whereas normal bile would not. I was able to confirm these observations in some measure, but noted that on exposure to air such bile became alkalinized more rapidly than normal bile. And, indeed, Rous, McMaster and Drury<sup>43</sup> have noted that if acid is added to such bile no precipitation occurs.

42. Oliver, S. F.: Effect of Bile Salts in the Urine on Routine Tests for Albumin, *J. Lab. & Clin. Med.* 7:743-745 (Sept.) 1922; Etiology of Gallstones, *J. Lab. & Clin. Med.* 8:242-250 (Jan.) 1923.

43. Rous, Peyton; McMaster, P. D., and Drury, D. R.: Observations on Some Causes of Gallstone Formation: I. Experimental Cholelithiasis in the Absence of Stasis, Infection and Gallbladder Influences, *J. Exper. Med.* 39:77-96 (Jan.) 1924; II. On Certain Special Nuclei of Deposition in Experimental Cholelithiasis, *ibid.* 39:97-116 (Jan.) 1924; III. The Relation of the Reaction of the Bile to Experimental Cholelithiasis, *J. Exper. Med.* 39:403-423 (March) 1924.

The Lichtwitz theory at least explains the sudden precipitation of gallstones, and also the lamination of calculi resulting from intermittent deposits, seen so often in the common stones. I have observed several interesting illustrations of the sudden precipitation of the entire bile content of the gallbladder. In one instance the patient had a laparotomy and during the exploration two large hard gallstones, about 5 cm. in length, were palpated. The gallbladder was otherwise collapsible. A pelvic operation was performed and the abdomen closed. Two days later the patient died from a pulmonary embolus. At necropsy, two large, hard cholesterin-rich gallstones were found, and also a soft, crumbly, brown substance, which was firm enough to be handled, and which when removed, in toto, formed a complete cast of the gallbladder

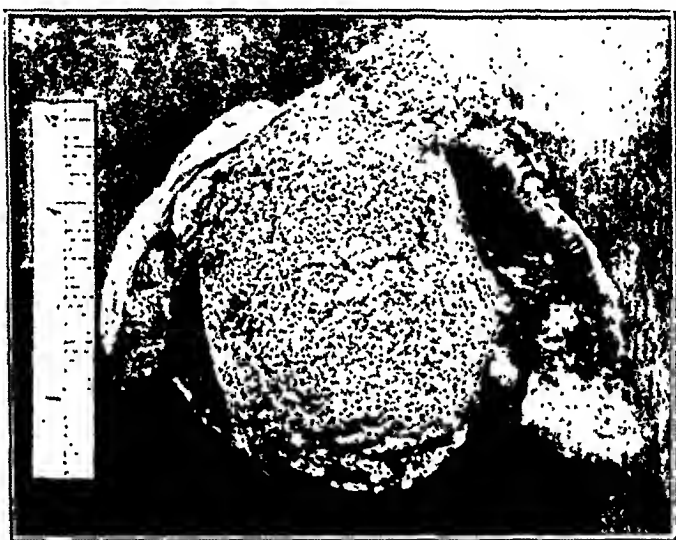


Fig. 8.—Small cholesterin stone, with massive precipitation of cholesterin material about it, completely filling the cavity of the gallbladder.

cavity. The chemist reported it 95 per cent cholesterol. Significantly enough, the gallbladder bile was alkaline.

An equally interesting case was found later, in which a cast of the entire gallbladder cavity was formed, even one of the leaflets of the valves of Heister being visible in the mold. The center of this mass was a radiate cholesterin stone about 1 cm. in length. The chemist reported that this central stone, which was relatively firm and probably very old, was "approximately 95 per cent cholesterol." The cast was a homogeneous mass of bile pigment and cholesterol (figs. 7 and 8).

These two cases illustrate the fact that a sudden massive precipitation of the entire cholesterin content of the gallbladder bile can occur in the gallbladder cavity, and they suggest that the usual laminations of the common gallstone occur in this manner, but that the precipitation is



checked before it is complete, by a recovery in the chemical equilibrium of the bile, which can occur when the excess cholesterin is removed by precipitation and the bile acid base balance is again restored.

#### SUMMARY

There are probably two types and two sources of gallstone formation: (1) the bilirubin calcium stone containing little or no cholesterol, and arising within the intrahepatic ducts, and (2) the cholesterol stone containing varying degrees of cholesterol and arising within the gallbladder cavity.

Disturbance of cholesterol metabolism of the body generally, or of the gallbladder wall locally, with a resultant increase in the cholesterol content of bile, is probably a primary factor in the formation of gallstones.

Stasis of bile and infection of the gallbladder are not essential to gallstone formation, but both are usually present with all stones.

Nuclei of some sort are invariably present, and are possibly essential to the actual formation of stones. Portions of cholesterol laden mucous membrane lying free in the gallbladder cavity probably form the nuclei for a large portion of cholesterin stones. Without a nucleus it is possible that the ingredients of stones pass out of the gallbladder.

These conditions, namely, an increase in the cholesterol content of the gallbladder bile, the presence of a nucleus and a change in the  $p_H$  value of the bile, particularly toward alkalinity, are probably the essential features of cholesterin stone formation in the gallbladder.

# UNUSUAL VERTEBRAL INJURIES

## REPORT OF CASES \*

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NEW YORK

The early recognition of a fracture or fracture-dislocation of the spine should not be a difficult task in the light of our present clinical and roentgenologic knowledge. The average physician feels that a person who is not paralyzed and who has not fallen from a considerable height is merely suffering from a strain of the back. The terms "fatality" and "permanent disability" invariably arise as a word picture in the mind of the physician and layman when thinking of fractures of the spine. The failure to request lateral views of the site of injury in addition to anterior posterior roentgenograms is to be condemned. The former are of far greater diagnostic value. Then again, the orthopedic surgeon is consulted late in the course of the condition, during which time the injured has developed an anxiety neurosis in addition to the already existing physical symptoms. This is hard to combat and the treatment and disability are therefore unnecessarily prolonged.

### ETIOLOGY

1. Mechanism A. Direct Violence: These cases are rare. B. Indirect Violence: A sudden forced hyperflexion of the spine as a result of falling from a height and landing on the back of the neck and shoulders; a heavy object falling on the flexed trunk, or a sudden muscular contraction in an attempt to lift a heavy object may be the cause of these cases.

2. Location: Fractures of the spine usually involve a single vertebral body. The site of election is the dorsolumbar segment extending from the eleventh dorsal to the third lumbar level. The first lumbar vertebra is the one most frequently affected. Fracture dislocations occur more frequently in the upper cervical and lower lumbar regions, or in the locations that are the most mobile.

### SUBJECTIVE PHENOMENA

1. Pain: A. May be referred along the course of the nerves arising from the injured levels. B. Usually is localized to within a small radius of the lesion. C. Is aggravated by attempts at movement of the spine. D. Is referred to the site of the injury when the top of the head is struck or when the patient jumps on his heels.

2. Weakness: A. Of the trunk. B. Of the extremities

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\* Cases presented before the Orthopedic Section of the New York Academy of Medicine, January, 1926.



Fig. 1 (case 1).—Range of flexion and extension one month after the accident.



Fig. 2 (case 1).—Degree of rotation one month after the accident.

OBJECTIVE PHENOMENA

1. Inspection: A, Gait, awkward and careful with the body tilted anteriorly, laterally or both. B. Contour, involvement of the cervical spine may result in a wry neck. The dorsal spine usually presents a small gibbus. The lumbar spine shows a flattening of the region and in addition a small posterior projection may be observed. These findings may be accompanied by a lateral deviation of the spine at the site of injury, and in some few instances an accompanying rotation.
2. Mobility of the trunk: With involvement of the normally mobile spine there is always a total or partial loss of motion either of the entire segment or of

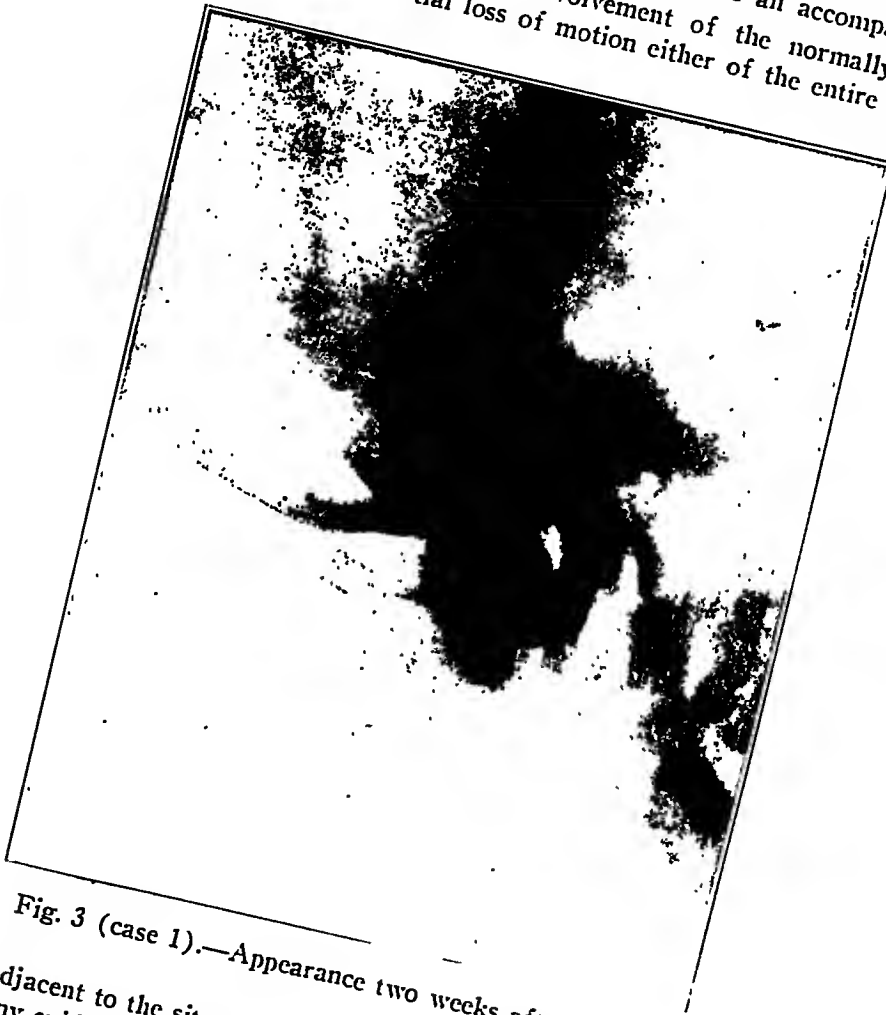


Fig. 3 (case 1).—Appearance two weeks after injury.

the vertebrae adjacent to the site of fracture. The middorsal spine when fractured gives little if any evidence of loss of motion because of its normal rigidity.

3. Palpation: Tenderness is an invariable accompaniment of fracture of the spine and is usually localized to within a short radius of the site of injury. Muscle spasm occurs with all attempts at movement and lends itself to palpation.

4. Neurologic Findings: Sensory changes may be observed in the regions supplied by the injured nerves, and aids in the localization of the exact level of traumatization. Reflexes are found to be hyperactive when the cord is edematous, and absent as a result of sectioning of the cord or from pressure necrosis due to prolonged cord edema. Paralysis of the muscles of the extremities or of the viscera may ensue as a result of cord edema, and is always noted when the cord is sectioned.

5. Roentgen-ray Observations: Whenever possible at least two views of the spine should be shown. A proper interpretation of the roentgenograms should include: A. Contour: angulation, lateral deviation and rotation. B. Shape of the vertebral bodies: compression, wedging and fragmentation. C. Intervertebral spaces: narrowed; irregular. D. Articular facets and their relationships to one another. E. Fracture of laminae. F. Fractures of transverse processes. G. Fracture of spinous processes and their relationship to one another (may be overlapped in dislocations). H. Productive changes denoting evidences of healing.

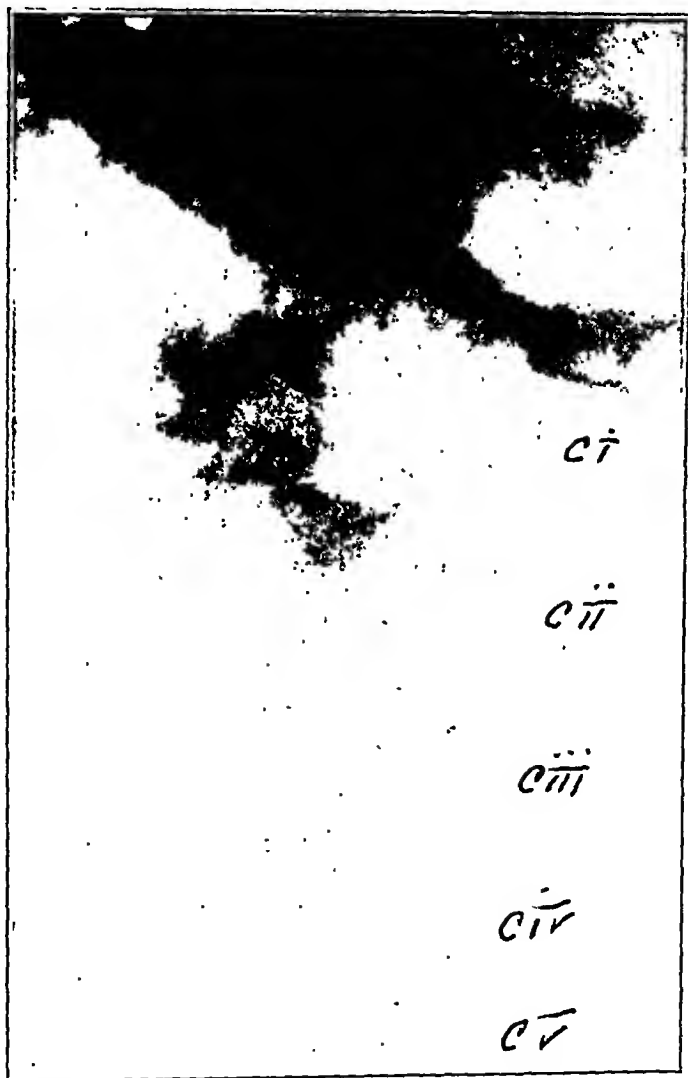


Fig. 4 (case 1).—Appearance one month after injury.

The following case reports are presented because of various unusual phenomena.

#### REPORT OF CASE

CASE 1.—P. D., a motorman, aged 46, was perfectly well until Nov. 1, 1923, when he lost his footing at the head of a flight of stairs and fell forward, landing at the bottom of twelve steps with his head acutely flexed against the wall. He remained unconscious for twenty minutes. He was removed to his bed, where he remained for two weeks, suffering intense pain for the first twenty-four hours.

Shortly thereafter the pain subsided, and was present only at attempts at movement of the neck. At the end of two weeks he was well enough to get about without support.

He reported to work on the fifteenth day following the accident. The company physician refused to permit him to return to his former occupation of elevated motorman, and suggested that a roentgenogram be made to determine



Fig. 5 (case 3).—Anteroposterior view of spine, April, 1924.

the extent of the injury. I saw the patient one month after the accident; the findings were normal except for slight restriction of the rotation of the neck to either side. The patient himself did not complain of pain, weakness or difficulty in swallowing. The roentgenograms brought by the patient showed a dislocation of the second cervical vertebra on the third for a distance of three-sixteenths inch; fracture of the odontoid process at its base with slight articulation, and a chip

fracture of the superior aspect of the lamina of the second cervical vertebra with little separation. The anterior posterior view was of no diagnostic value.

The patient was fitted with a leather collar and received graduated physical therapy. The collar was worn for a period of three months, at the end of which time the patient was discharged as cured and allowed to return to his former occupation. He was last seen in January, 1926, when he stated that he has continued at work and is perfectly well.

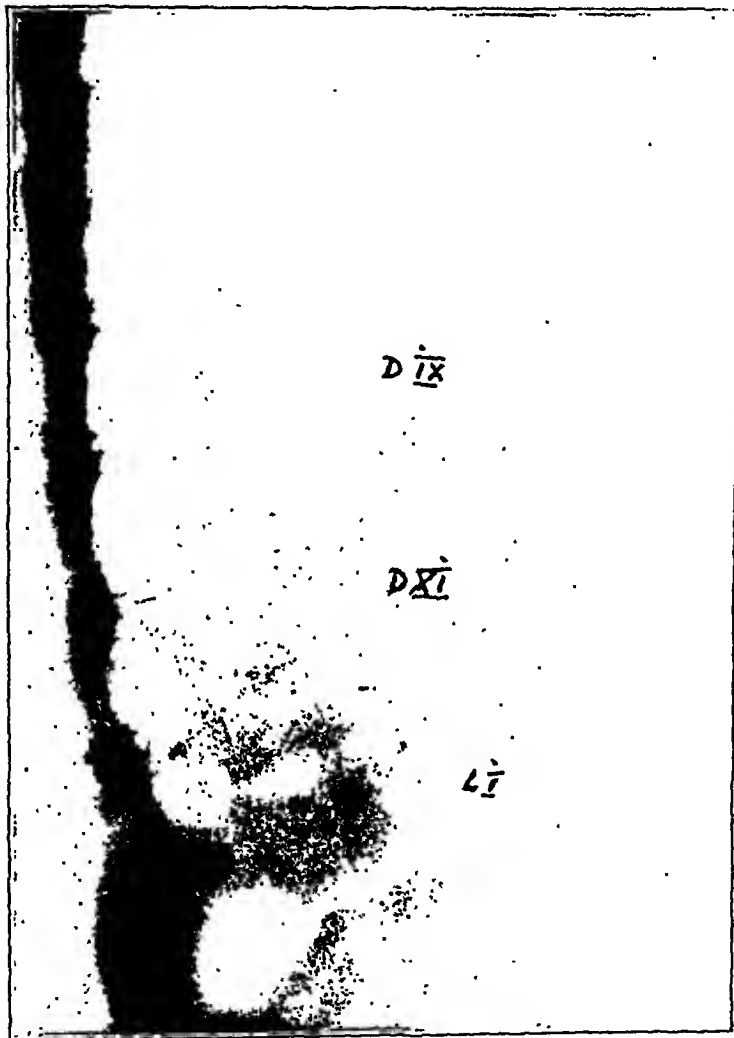


Fig. 6 (case 3).—Lateral appearance, April, 1924.

The unusual features in this case are the inability to recognize the lesion without the use of the roentgen ray, the lack of proportion between the roentgen-ray findings and the clinical phenomena; the rapid recovery, and the absence of neurologic signs.

CASE 2.—H. K., a man, aged 59, a sexton and "handy man," was well until Sept. 9, 1920, when while painting the front of a house on a scaffold, he was thrown to the ground by the breaking of a rope. He fell a distance of 14 feet and landed on the back of the neck and shoulders. He did not lose consciousness. He was removed to his home, where he remained in bed for two weeks, being

treated during this time for a sprain of the neck. He was dissatisfied with his physician so placed himself under the care of a chiropractor from whom he received twenty spinal adjustments. Because of failure to obtain relief from pain he sought the advice of another physician, who ordered roentgenograms. The latter, according to the physician, were negative. After about nine months of unsuccessful attempts at alleviation of the pain he came to me.

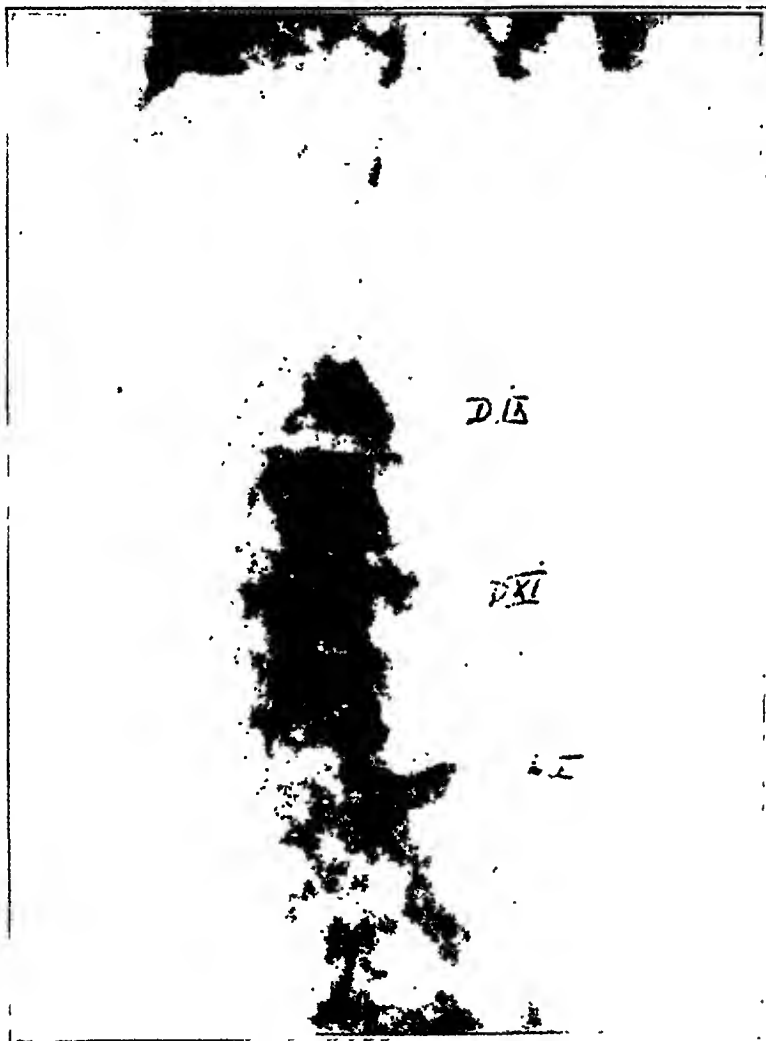


Fig. 7 (case 3).—Lateral appearance, November, 1925.

At this time he complained of persistent pain of the neck, headaches, weakness of the upper extremities and inability to hold the head erect. Examination revealed in addition to the foregoing, a contraction of the anterior muscles of the neck which maintained the cervical spine in an attitude of marked flexion, so much that the chin touched the sternum. Movements of the cervical spine were restricted in all directions, and accompanied by muscle spasm and pain. There was no difficulty in swallowing, no voice changes and no evidence of paralysis. The grip on both sides was weak. No sensory changes were found. The reflexes of the upper extremities were exaggerated; those of the lower extremities were active and equal.



Roentgenograms taken soon after the initial examination revealed in the anterior posterior view an indistinctness of outline of the bodies of the fifth, sixth and seventh cervical vertebrae with an obliteration of the intervertebral spaces between these segments. The vertebrae above and below the site of injury were normal in appearance. The lateral view showed a displacement of the fifth cervical posteriorly for a distance of one-eighth inch. The bodies of both the fifth and the sixth cervical vertebrae were irregular in outline, compressed from above downward and increased in their transverse diameter. The intervertebral spaces were markedly diminished. There were also present proliferative changes of the anterior borders of the fifth and sixth cervical vertebrae.

The diagnosis was fracture dislocation of the cervical spine with involvement of the fifth and sixth cervical vertebrae. The patient was treated conservatively; he was fitted with a leather collar and received physical therapy. He later devel-

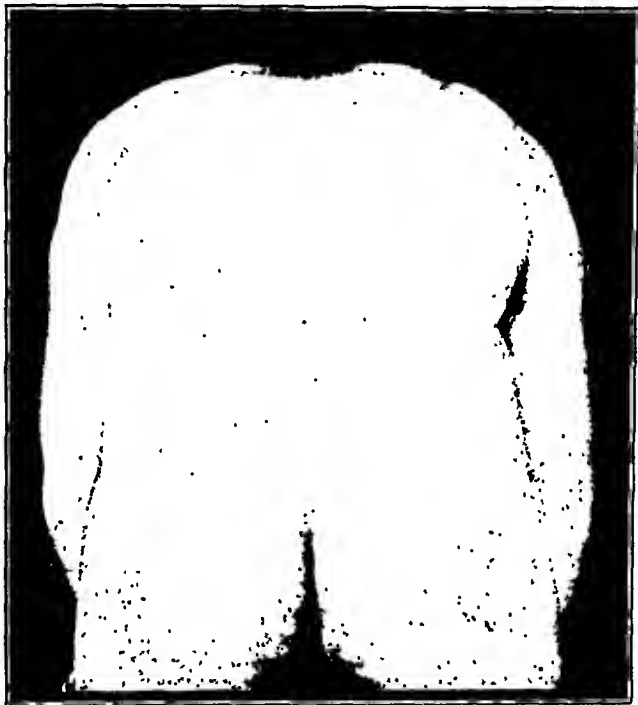


Fig. 8 (case 5).—Degree of flexion, November, 1921, and gibbus.

oped radicular symptoms as a result of pressure due to the proliferative bone changes in the region of the intervertebral foraminae. In addition to these he developed an anxiety neurosis. After four years he is still under treatment by the insurance company.

The points of interest are failure of early recognition of the lesion and late nerve manifestations.

CASE 3.—R. F., a chauffeur, aged 20, was first observed April 22, 1924, complaining of pain and stiffness of the back and weakness of the lower extremities. He was well until March 12, 1924, when he attempted to back an automobile on to an elevator on the third floor of a garage; the elevator having been raised to the floor above, the machine dropped through the shaft and landed bottom side up, the patient being found underneath the car. He was removed while unconscious

to a nearby hospital where he remained for three weeks. He was not paralyzed at the time, nor was there any evidence of incontinence. He was discharged from the hospital with a diagnosis of sprain of the back, even though roentgenograms were made.

The patient was well developed; he walked awkwardly, with the body tilted slightly forward and with the right shoulder elevated, and was able to walk only

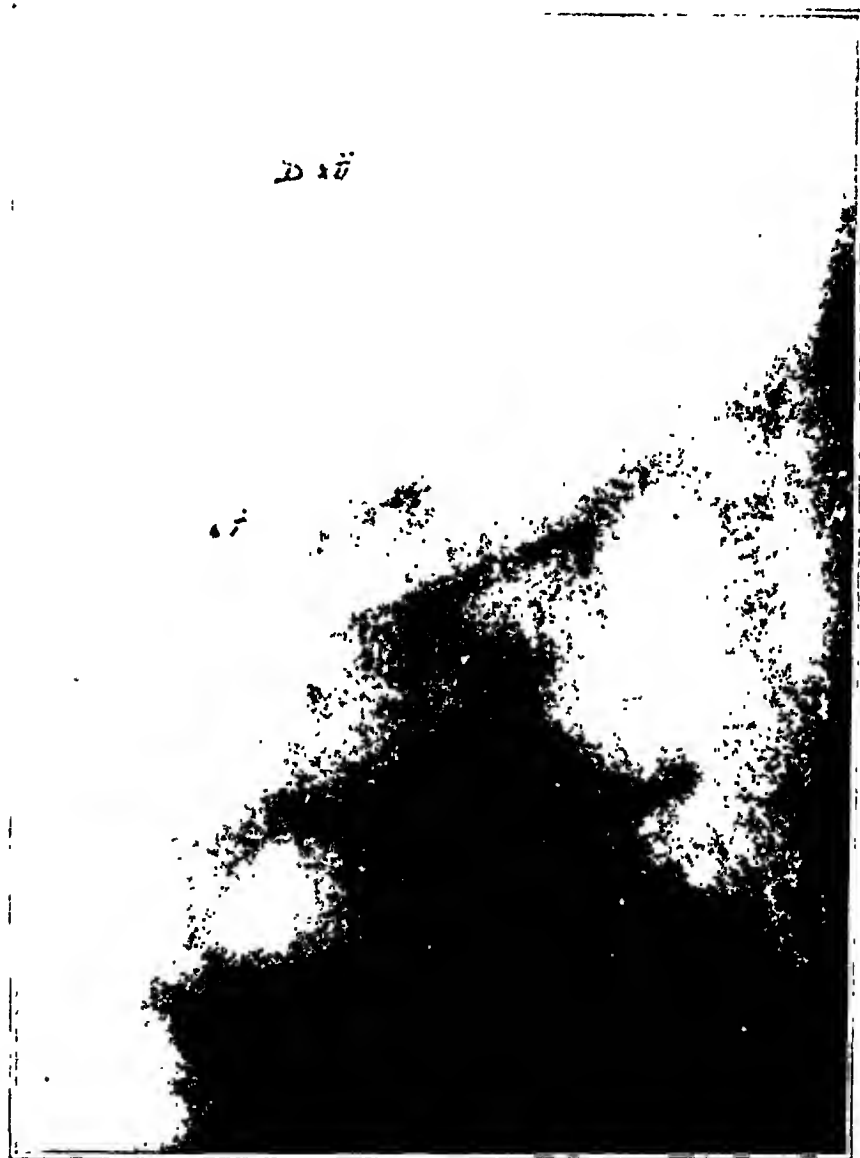


Fig. 9 (case 5).—Lateral appearance showing fracture of first lumbar vertebra, November, 1921.

a short distance without complaining of pain and weakness. The spine showed the presence of a mild posterior and lateral curvature to the left in the dorsolumbar region. Movements were restricted in all directions, and were accompanied by muscle spasm and pain. Jumping on the heels or striking the top of the head caused the pain to be localized to the first lumbar vertebral region. There was a good deal of muscle tenderness on either side of the spine from the level of

the eighth dorsal to the first lumbar segment. There were no sensory changes. The knee jerks were exaggerated; the ankle reflexes could not be elicited; the abdominal and cremasteric reflexes were active and equal.

Roentgenograms, April 22, 1924, showed the spine deviated to the left in the dorsolumbar region, and compression of the ninth, eleventh and first lumbar vertebrae with an increase in the transverse diameters. There was some irregularity of the inferior surface of the twelfth dorsal vertebra and diminution of the intervertebral spaces between the eighth and ninth dorsal, ninth and tenth dorsal and between the tenth and eleventh dorsal regions. The lateral view showed the presence of a posterior curvature and wedging of the involved vertebral bodies, and in addition fracture of the anterior portions with only slight separation. The intervertebral spaces were only slightly diminished.



Fig. 10 (case 5).—Amount of flexion possible twenty-eight months after accident.

The patient was admitted to the Hospital for the Ruptured and Crippled and placed on a convex stretcher frame without traction. He remained at the hospital for six weeks, receiving daily massage of both the back and the extremities. As a result of this the deformity became almost completely corrected; the knee reflexes became normal. The patient was discharged wearing a plaster jacket. After discharge from the hospital the jacket was renewed from time to time until June, 1925, when a plaster corset was applied, allowing for the institution of physical therapy. The corset was discarded by the patient in November, 1925.

Examination since then showed that the patient is able to flex the spine 75 degrees, extend the back 10 degrees and bend to either side about 25 degrees. He has been working at his former occupation for the last year, and complains neither of pain nor of tiredness. The roentgenogram of November, 1925, shows in the anterior posterior view a slight deviation of the spine to the left in the dorso-lumbar region and productive changes of the borders of the twelfth dorsal and

first lumbar vertebrae laterally with fusion. The lateral view reveals complete healing of the fractures of the bodies with the presence of some productive changes of the anterior borders.

The result of conservative therapy has been most gratifying in this instance. This case is unusual because of the involvement of three vertebral bodies separated by normal undisturbed vertebrae.

CASE 4.—G. W., a milk wagon driver, aged 34, was well until August, 1924, when his wagon was struck by an automobile truck and the patient was thrown out. He was removed to a nearby hospital, and was discharged at the end of two weeks



Fig. 11 (case 5).—Amount of side bending possible.

with a diagnosis of sprain of the back and muscular contusions. For the following three months he received baking and massage of the back without relief.

The patient came to me because of the persistence of pain, weakness and inability to work. Examination, November, 1924, showed a well developed man walking about without assistance and presenting a moderate posterior curvature of the dorsal region. There was a small but definite projection at the level of the spinous process of the first lumbar vertebra. Movements of the lumbar spine were partially restricted in all directions, more especially in flexion and extension. These movements were accompanied by muscle spasm. There was tenderness on either side of the spine from the level of the eleventh dorsal to the second lumbar vertebra. The reflexes were active and equal. No sensory changes could be found. Jumping on the heels localized the pain to the first lumbar segment; striking the top of the head did not cause any pain to the injured site.

A roentgenogram of Nov. 29, 1924, disclosed in the anteroposterior view an obliteration of the intervertebral space between the twelfth dorsal and the first lumbar bodies. The lateral view showed the presence of a mild posterior angulation of the dorsolumbar region with the apex at the level of the first lumbar vertebra. The first lumbar vertebral body was wedged, and its anterior superior margin was irregular. There was a diminution of the intervertebral space. The diagnosis was compression of the first lumbar vertebra.

Because of the patient's anxiety to return to his former occupation at an early date the spine was fused from the level of the eleventh dorsal to the fourth lumbar

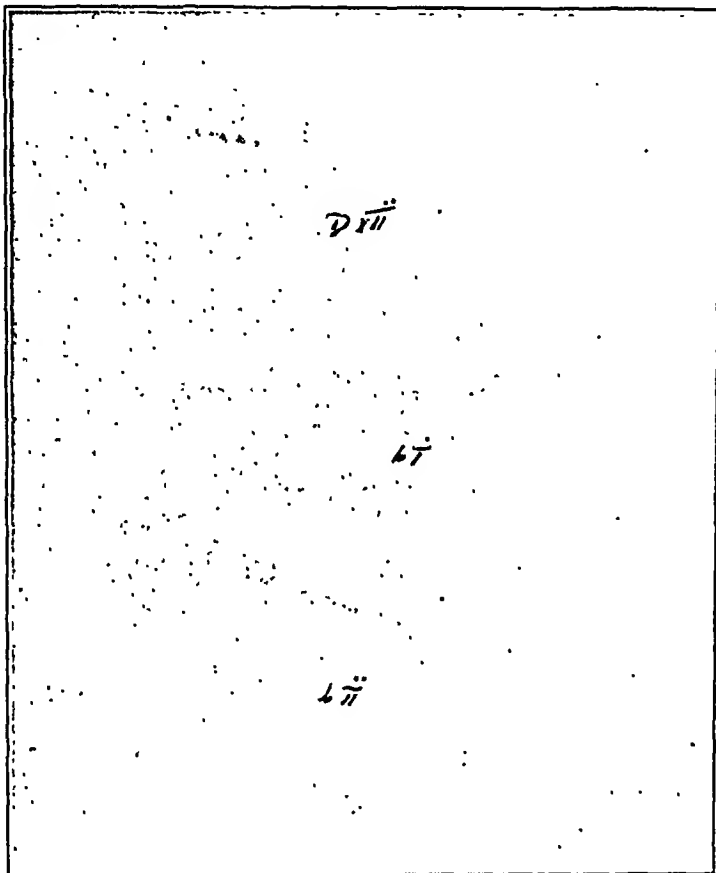


Fig. 12 (case 5).—Lateral appearance, September, 1923.

vertebra. The patient was able to perform light work three months after the operation, and return to his former occupation one year after my first examination, or fifteen months after the accident.

The features of interest in this case are failure of recognition of the lesion by the hospital staff; absence of neurologic findings, and the ability of the patient to return to his former occupation at a comparatively early date. It is often stated by authorities that a person with a fracture of the spine is unable to return to his former occupation, especially if he is a laboring man.

CASE 5.—G. L., a man, aged 24, a counter man in a restaurant, was well until May, 1921, when while working on board ship he fell 20 feet through a shaft, landing on his back. After two weeks' rest he was able to resume his duties until the ship landed. Since that time he has been unable to work because of persistent pain across the midportion of the back and weakness. He was observed some six months later, when he complained of pain, stiffness and weakness of the spine. The examination revealed findings similar to those described in the preceding case. The roentgenogram disclosed a compression fracture of the first lumbar vertebra. This patient was treated conservatively for two years, at the end of which time there was a complete return of function of the spine and he was able to work sixteen hours a day as a counter man in a restaurant. His duties also included rather laborious tasks. The last set of roentgenograms, taken about



Fig. 13 (case 7).—Depression immediately above the sacrum.

twenty-eight months after the accident, showed that a bridge of bone had formed between the superior anterior border of the first lumbar vertebra and the inferior anterior border of the body above. This bridge of bone became fused to the adjacent vertebral body, thus resulting in a permanent cure.

This case demonstrates the value of conservative treatment in young persons.

CASE 6.—T. W., a carpenter, aged 35, was well until October, 1923, when he fell about 18 feet from a scaffold, landing on the buttocks. He remained at home for a few days and then returned to work, but he had to stop work after one week because of increasing pain in the lumbar region; the pain radiated down the left leg. This patient received baking and massage for several months without improvement, and was referred to me for an opinion as to the cause of the disability. It was said that for years he had had a rotary lateral curvature and that the injury had little to do with the present condition.

Examination, July 29, 1924, showed the patient in good general condition; he walked without a limp, but with a tilting of the body to the left. The right shoulder was maintained higher than the left. The anterior superior spines were on equal levels. There was a loss of the normal lumbar curve, and an accompanying prominence of the left lumbar region. Flexion of the spine was restricted to two-thirds normal; extension was one-fourth normal; bending to either side, one-half



Fig. 14 (case 7).—Anterior-posterior appearance of site of injury.

normal. There was an appreciable deviation of the spine to the left in the upper dorsal region, and to the right in the lumbar location, with the apex of the curve (lumbar) at the level of the third lumbar vertebra. There was a prominence of the spinous process of the third lumbar vertebra and tenderness on either side of the spine in the upper lumbar region. Movements of the spine were accompanied by muscle spasm. The left lower extremity measured one-half inch (1.27 cm.) less

in circumference than its fellow. The limbs were of equal length. Flexion of the extended left lower extremity was restricted and painful. The reflexes were active and equal, and there were no sensory changes.

Roentgen-ray examination showed a deviation to the left in the lumbar spine and an accompanying rotation of the vertebral bodies. The body of the third lumbar vertebra was compressed in its right half and displaced toward the left for approximately one-half inch. There was a separation of the articular facets of the third and fourth lumbar vertebrae. The intervertebral disk between the third and fourth lumbar vertebrae was markedly diminished, and that between the second and third was exaggerated. In the lateral view, the body of the third

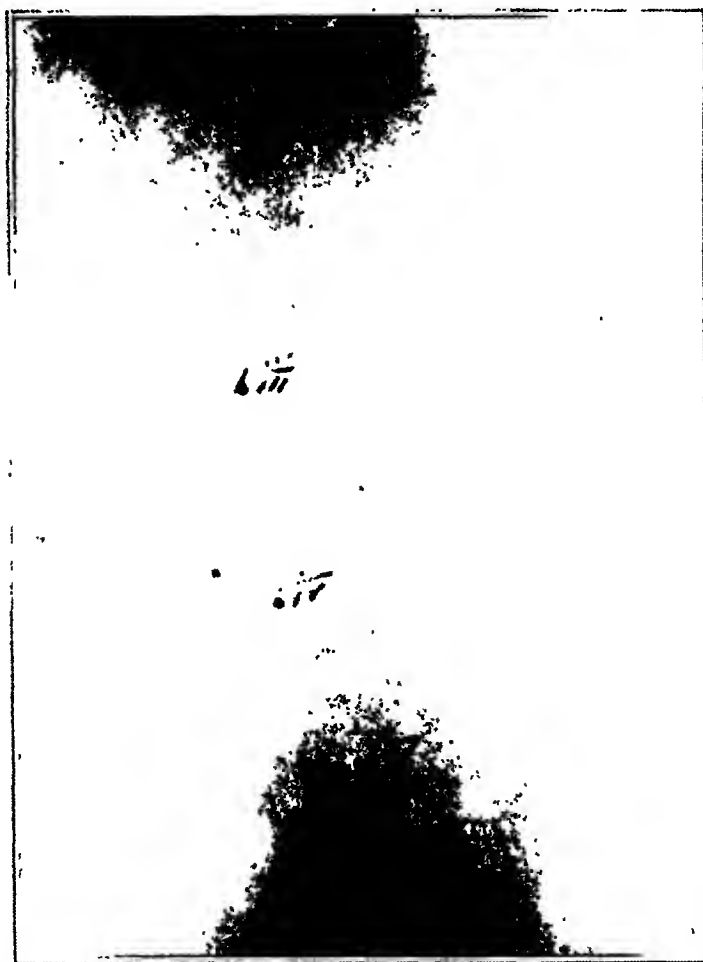


Fig. 15 (case 7).—Lateral appearance showing the dislocation of the fourth lumbar vertebra.

lumbar vertebra was displaced forward on the fourth. The intervertebral space was obliterated between the two bodies. The diagnosis was fracture dislocation of the third lumbar vertebra accompanied by a pathologic rotation of the spine.

The unusual feature of this case was the marked amount of rotation of the spine which may accompany a fracture dislocation. That the rotation did not antedate the injury was evidenced by the fact that the remaining segments of the spine showed no distortion (wedging and



CASE 7.—P. M., a laborer, aged 45, was first observed in December, 1924, at the Cornell Clinic complaining of pain across the lower part of the back and down the lower extremities posteriorly of several weeks' duration. The patient had worked for the previous twenty years at heavy manual labor and remained well until several weeks before admission, when he slipped down several iron steps while carrying a load of wood on the outstretched forearms.

He was well developed. He walked somewhat awkwardly and carefully, presenting a stiff back with a list of the body anteriorly. The spine from below upward was flattened up to the level of the crests of the ilia; at this site there was a horizontal ledge one-half inch in depth. From here upward the spine was found to be deviated slightly posteriorly. The depression was at the level of the spinous process of the fourth lumbar vertebra. Movements of the spine were moderately free above this region. Extension of the spine was completely restricted. The reflexes were equal, and there were no sensory changes. The extremities were of equal length and presented no evidence of atrophy.

The anterior posterior roentgenogram of the lumbar spine showed a diminution of the vertical distance of the fourth lumbar vertebra. The spinous processes of the fourth and fifth lumbar segments were in close approximation. The intervertebral space between the fourth and fifth bodies was obliterated. The lateral view showed an anterior displacement of the fourth lumbar on the fifth for a distance of one-half inch. There was no evidence of fracture of the vertebral bodies. There was, however, a haziness in the regions of the articular facets between the fourth and the fifth lumbar vertebrae; all other facets could be made out quite clearly.

The patient was admitted to the Hospital for the Ruptured and Crippled in January, 1925, and was operated on. At the time of operation it was noted that the spinous processes of the lower two vertebral bodies overlapped. It was also observed that the last lumbar vertebra could be displaced anteriorly, and when the pressure was released the body would return to its former position. The fourth segment could not be so moved. The region of the articular facets between the fourth and the fifth segments was found to be soft and resembled callus formation. The patient was discharged from the hospital four weeks after operation wearing a plaster jacket. At the present time he is wearing a Knight spinal brace. The movements of the spine are free and painless. There is no muscle spasm. About two months before this article was written he discarded the brace and worked for several weeks at heavy manual labor, but had to stop work because of a recurrence of pain as a result of a sudden twisting strain. He has been advised to return to light work for the present.

The reason for the delayed recovery probably was the failure to insert a bone inlay graft at the time of the operation in addition to the fusion; the patient would not consent to the removal of a tibial graft.

CASE 8.—A. E., a carpenter, aged 54, was well until Nov. 20, 1922, when he slipped down a ladder 14 feet, landing on the base of the spine. He was removed to his home, where he remained for three days. He then returned to work for three days, but suffered severe pain. After that time he was totally disabled, and received various forms of physical therapy for several months without relief.

In September, 1923, the patient complained of pain and disability. The pain was in the lower lumbar region and radiated down the left leg. He walked awkwardly without assistance. In standing he held the left leg in advance and bent the body forward. Motions of the spine were moderately restricted in all

directions, and especially in extension. Striking the top of the head caused no pain in the spine. There was a loss of the normal lumbar curvature, but no evidence of angulation of the spine and no depression immediately above the sacrum. There was tenderness of the left gluteal region and along the course of the left sciatic nerve. The left Kernig sign was positive. The hips were freely movable and painless. The lower extremities were of equal length. The left thigh and calf measured one-half inch less in circumference than the right. The knee reflexes were active and equal, and the ankle reflexes could not be elicited.

The anterior posterior roentgenographic view showed slight deviation of the lumbar spine to the right. There were changes indicative of osteoarthritis of the second and third lumbar vertebrae, and a tilting forward of the fifth lumbar vertebra as evidenced by a visualization of the entire proximal surface. The lateral view showed a displacement of the entire lumbar spine on the sacrum for about three-sixteenths inch. The diagnosis was traumatic spondylolisthesis and osteoarthritis.

The patient was admitted to the Hospital for the Ruptured and Crippled and a spine fusion combined with an autogenous bone inlay graft from the tibia was performed in September, 1923. After the operation he wore plaster jackets and finally a Knight spinal brace was applied to facilitate the administration of physical therapy. His condition has been improved locally. About one year after the operation he obtained a position as a bank watchman, and continued at this occupation for one year. Since then he has developed a radiculitis, due probably to the osteoarthritis, and is now incapacitated.

The unusual feature in this case is the presence of a spondylolisthesis of traumatic origin.

# SOLID TUMORS OF THE URACHUS \*

LEO BRADY, M.D.

BALTIMORE

Articles on urachal cysts are published not infrequently and abdominal surgeons are fully aware of the importance of this condition. On the other hand, the occasional development of solid tumors has not been sufficiently appreciated. The occurrence of a case of the latter kind in my private practice has led me to look up the literature and find out just how many such growths have been reported.

## REPORT OF CASE

*History.*—M. K., a woman, aged 43, was referred to me by Dr. Caleb Athey because of lower abdominal pain and irregular menstrual bleeding. Her family history was unimportant. She had had eleven pregnancies with normal deliveries. There was no history of urinary or gastro-intestinal trouble. Her menstrual periods, until the onset of the present trouble, had occurred regularly, lasting four days and unaccompanied by pain. For six months the menses had occurred twice a month; they had been more profuse than formerly and there had been some bleeding between the periods. Since her first pregnancy, the patient had had a moderate amount of leukorrhea, but this had not increased in amount during the present illness. That she had an umbilical hernia she had known for several years. The symptom, however, that brought the patient to Dr. Athey was pain in the middle of the lower abdomen. This had been present for two years, but in the last few months had increased greatly in severity.

*Examination.*—The patient was a stout woman who complained of pain in the lower abdomen. The general physical examination revealed no abnormalities. The lower portion of the abdomen appeared somewhat distended. There was an umbilical hernia, the ring of which was 5 cm. in diameter. On palpation of the lower part of the abdomen one could outline a firm mass that extended in the midline from the symphysis pubis to within 2 cm. of the umbilicus. On pelvic examination, the perineum was found markedly relaxed. There was a large cystocele. The cervix was slightly lacerated and unusually firm in consistency. I was not able to differentiate the fundus from the abdominal tumor.

*Diagnosis.*—The diagnosis was myomata uteri, with a relaxed vaginal outlet. Because of the history of metrorrhagia and the unusually firm consistency of the cervix, it was decided that a dilatation and curettage of the uterus should be performed, a small piece of tissue excised from the cervix and these specimens examined microscopically so as to rule out carcinoma before the hysteromyomectomy was carried out.

*Operation.*—This was performed at the Church Home and Infirmary, Jan. 2, 1926. After microscopic examination of frozen sections of the uterine curettings and tissue excised from the cervix had shown that no malignancy was present, a lower abdominal midline incision was made. Under the recti muscles, but lying outside the peritoneal cavity was a large tumor which extended from

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\* From the Department of Gynecology, Johns Hopkins University Medical Department and Hospital.

the region of the bladder to within a few centimeters of the navel (fig. 1). The recti muscles and their fascias were quite distinct from this tumor and were not even adherent to it. The base of the tumor reached to and rested on the bladder, but was only lightly adherent to it. Through the properitoneal tissue both above and below the tumor were many large veins. The tumor was gray and had a definite capsule. Although situated exactly in the midline of the pro-

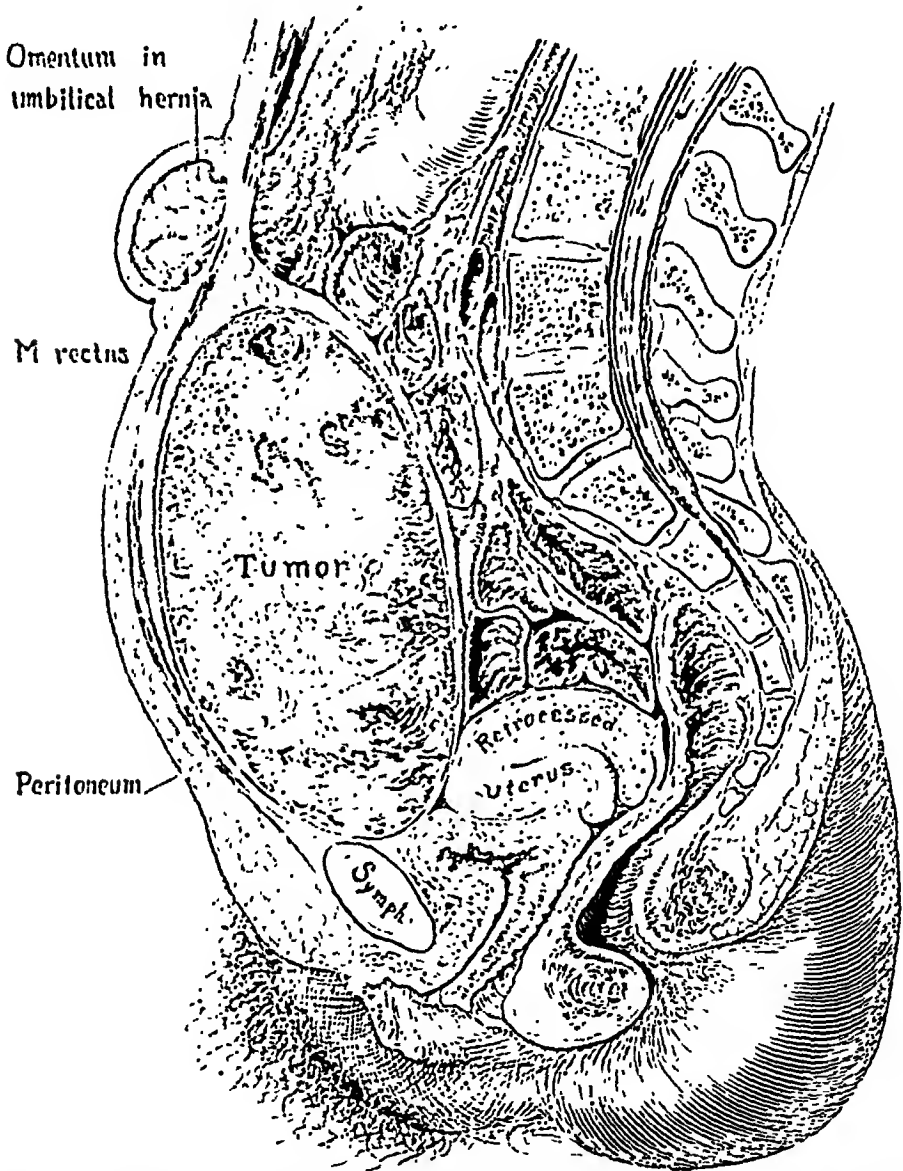


Fig. 1.—Urachal myoma, showing its size and its position in the properitoneal tissue between the recti muscles and the peritoneum (gross section).

peritoneal tissue, it derived its blood supply from vessels entering it from the two sides. The tumor was easily removed without being ruptured or torn. The peritoneal cavity was then entered. A large piece of omentum was found caught in the umbilical hernia. The uterus was normal in size and contained no fibroids; the large properitoneal tumor had pressed it backward into a position of retrocession. The fallopian tubes and the ovaries were normal. The round ligaments contained no myomas or adenomyomas from which the large properitoneal tumor



Fig. 2.—Myoma of the urachus as it appeared after being removed; the dilated lymphatics coursing over its external capsule are prominent.



Fig. 3.—Urachal tumor (cut surface) for the most part presenting the whorl-like appearance of a myomatous growth; scattered through the firm, opaque tissue are islands of semisolid, spongy, translucent material such as one sees when hyaline degeneration has occurred in a myomatous growth.

might have arisen. Inspection from inside the abdominal cavity of the portion of the peritoneum against which the tumor had rested showed nothing unusual. Since the patient was 43, gave a history of excessive uterine bleeding and since the peritoneal cavity had already been entered, a high supravaginal hysterectomy was performed. The umbilical hernia was then corrected in the usual way, and finally the relaxed vaginal outlet was repaired. The patient stood the operation well and one month later left the hospital in good condition.

*Pathologic Report.*—The uterus was of normal size and, grossly, not abnormal. Microscopic examination of the endometrium showed only moderate hyperplasia. The tumor removed from the peritoneal tissue of the lower abdomen was ovoid in shape (fig. 2), weighed 600 Gm. and measured 14.5 by 9 by 10 cm. The external surface was gray and presented everywhere an unbroken capsule. Numerous dilated blood vessels coursed over its surface and what was especially striking was the great dilatation of the lymphatics. Here and there, attached to its external surface, were bits of connective tissue and fat which were removed with the tumor. Nowhere was there any definite pedicle or stalk leading from the tumor. The cut surface (fig. 3) presented for the most part the whorl-like appearance of a myomatous growth. Scattered through the firm, opaque, grayish white tissue were islands of semisolid, spongy, translucent material such as is associated with hyaline degeneration in a myomatous growth.

The microscopic sections showed smooth muscle tissue with considerable hyaline degeneration in places. The external capsule, which nowhere had been broken through, was made up of fibrous tissue. There was no evidence of malignancy. The diagnosis was fibromyoma of the urachus.

There have been reported, including my own, twenty cases of solid tumors arising from the urachus.

Hue and Jacquin<sup>1</sup> in 1868 described the first of these tumors, but did not themselves recognize the condition, reporting their case as one of colloid cancer of the umbilicus and of the anterior abdominal wall. As was pointed out by Frank<sup>2</sup> in 1893, however, one has only to read the original account of these two French writers to feel certain that they were dealing with a primary tumor of the urachus. The following is a summary of their case:

A soldier, when 45 years old, noticed for the first time a firm, smooth tumor about the size of a chestnut which was situated in the midline of the anterior abdominal wall so as somewhat to raise the umbilicus. The regimental physician, thinking that he had to deal with a collection of pus under the umbilicus, made an incision into this tumor but obtained only a small quantity of dark hemorrhagic fluid. After the operation the edges of the incision, instead of healing, continued to spread further and further apart. By the sixth week after the incision into the tumor, there had developed a foul smelling fungating mass, the size of a pigeon's egg, in the region of the navel of which no trace remained. In the center of this fungating mass was a small opening from which purulent fluid poured. It was found possible to introduce a stylet into this opening for a dis-

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1. Hue and Jacquin: Cancer colloïde de l'ombilic et de la paroi abdominale antérieure, ayant envahi la vessie, *Union méd.* 6:418, 1863.

2. Frank, Theodor: Zur Casuistik der Urachustumoren, inaugural dissertation, Würzburg, 1893.

tance of 3 cm. The surrounding skin had by this time lost its natural elasticity and taken on a violet color. The general condition of the patient became bad so rapidly that, although a diagnosis of cancer was made, it was felt that further surgical procedures were not indicated. Ten months after the small lump had been noticed under the umbilicus, the entire anterior wall from the navel to the symphysis pubis had become converted into an indurated, compact fungating mass with three fistulas leading into it. Microscopic examination of a piece of tissue removed from the mass showed in the midst of an amorphous substance free nuclei with regular contours and granular contents and also many small round cells. During the last few months the patient complained bitterly of strangury and frequency of urination. Fourteen months after the tumor was first noticed the patient died.

At necropsy the recti muscles were found completely transformed into a gelatinous colloid mass. No trace of muscle fibers remained. The parietal peritoneum under the tumor and the vertex of the bladder had undergone a similar transformation. The posterior surface of the bladder was normal. The prostate showed no abnormalities. In the bladder cavity were two friable gelatinous masses which arose from one base on the anterior superior portion of the bladder at about the point where the urachus was attached to the bladder. These masses appeared to be continuous with the colloid material on the external surface of the vertex of the bladder. Microscopic examinations of gelatinous material in the anterior bladder wall and of the masses in the bladder all showed the same picture as that given by tissue removed from the tumor starting below the umbilicus, but no detailed account of the microscopic picture presented by these tumors is given. It is of interest that Laënnec considered the tumor to be a colloid gelatinous cancer; Virchow thought that it was a hyaline or gelatinous myxoma; J. Müller, that it was a gelatinous sarcoma. Certainly the patient died from a rapidly growing malignant tumor which, from its point of origin in the midline immediately below the navel and its rapid invasion of the umbilical area, with later extension to the bladder, almost certainly had arisen from the urachus and was not a primary carcinoma of the umbilicus. That it is difficult to decide on the exact type of cancer in this case can be understood from the differences in the diagnoses made by such authorities as Virchow, Müller and Laënnec. Possibly, the description of the microscopic observations seems to agree best with that of a sarcoma.

Hoffmann<sup>2</sup> in 1870 reported the second case of urachal tumor. His patient was born with a patent urachus through which urine was discharged at the umbilicus until the age of 3, when following the use of caustics the opening at the umbilicus closed and the patient experienced no further trouble from this condition until he was 27. At that time, however, he noticed an indurated area in the midline of the abdomen between the symphysis and the umbilicus. This area gradually increased in size, extending laterally and vertically so that the umbilicus became prominent. Tenesmus and polyuria next developed and, finally, there was a discharge of purulent material from the umbilicus. The patient died about one year after the tumor was first noticed, the immediate

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3. Hoffmann, Carl: Zur pathologisch-anatomischen Veränderung de Harnstrangs, Arch. d. Heilk. 11:373, 1770.



cause of death apparently being a peritonitis caused by perforation of the malignant tumor into the peritoneal cavity. Microscopic examination showed it to be a carcinoma of the squamous cell type. In view of the fact that at necropsy a canal was found extending from the umbilicus to the bladder, this case should be considered one of primary carcinoma developing in a patent urachus with secondary involvement of the bladder and umbilicus.

Aveling's case of urachial tumor,<sup>4</sup> which was the next to be reported, is of special interest to me because the tumor he described resembles more closely the one in my case than any other I have been able to find mentioned in the literature.

The specimen in this case was shown, March 10, 1886, before the British Gynecological Society and was at once referred to Dr. Bland Sutton for diagnosis. April 28, 1886, Dr. Sutton<sup>5</sup> presented the following report:

The tumor is ovoid in shape and measures 10 inches in length and 7 inches in width. It weighs four and three quarter pounds. The growth is surrounded by a distinct and thick fibrous capsule. On section, the tissue is of a dirty white color and the cut surface looks like a sponge. Inside the growth, six or seven hard nodules of the size of walnuts could be felt; these, when dissected out and divided, looked like small leiomyomata such as exist in the uterus, presented the same whorled arrangement of the fibers, and agreed with them histologically. Microscopic examination of the tumor showed that the outer portion consisted of unstriated muscle fibers, some of them being of large size. Internal to this, the cells assumed more the shape and character of those seen in spindle cell sarcomata, while the gelatinous material contained in the loculi is the result of mucoid degeneration of the sarcomatous element.

Although the age of the patient and the clinical history is not given by either Aveling or Sutton in their notes on this case, the microscopic and macroscopic descriptions of this tumor would suggest that the growth was not malignant. The gross and histologic description speaks of non-striated muscle, and the whole appearance of the tumor suggests a myoma. The areas that were supposed to be sarcomatous may readily have been simply hyalinized fibroid nodules. This interpretation of Aveling's case is also accepted by Cullen, who discussed it in his *The Umbilicus and Its Diseases*.<sup>6</sup> Figure 4 is a photograph of the original picture of Aveling's tumor as it appeared in the 1886 report of the British Gynecological Society.

Frank<sup>2</sup> in 1893 reported a case of sarcoma which probably had developed in the sheath of the urachus in an 11 year old boy. There

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4. Aveling: *Brit. Gynæc. J.* 2:56, 1886-1887.

5. Sutton, Bland: *Brit. Gynæc. J.* 2:387, 1886-1887.

6. Cullen, T. S.: *The Umbilicus and Its Diseases*, Philadelphia, W. B. Saunders Company, 1916.

was no history of any difficulty in infancy around the navel or of any urinary symptoms. The condition began with loss of appetite. A few weeks later a tumor appeared in the midline of the abdomen and quickly extended down to the symphysis. At operation, performed six months after the tumor had been first noticed, the recti muscles were found invaded by the growth as was also the outer wall of the vertex of the bladder, and when the peritoneum was opened metastatic sarcomatous nodules were found in the omentum. These findings along with the description of the microscopic sections taken from the tumor left no doubt of the correctness of the diagnosis of sarcoma. The patient recovered slowly from the operation and was well two months later.

Fischer<sup>7</sup> in 1894 reported the following case:

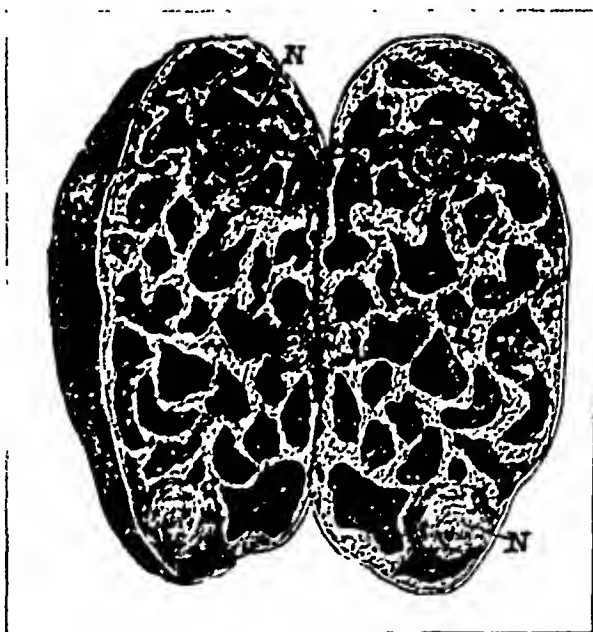


Fig. 4.—Aveling's tumor, an account of which was published in 1886 in the *British Gynecological Journal* (copy of photograph). That it has an external capsule is evident; the cut surface shows definite myomas and the tissue between these tumors resembles that seen in hyaline degeneration.

A man, aged 32, remembered that in his youth, when he passed urine, his navel would become moist. Later, this symptom disappeared. At the age of 32, he for the first time felt a tumor the size of a pigeon's egg under his navel. From then on the growth of this tumor was constant. In a few months burning on urination commenced and a sediment in the urine was noticed. Ten months after he had first noticed the tumor the patient consulted a physician as his urinary symptoms had become severer and the tumor much larger. The family physician, thinking that the tumor was an abscess as it felt rather soft and was in part

7. Fischer: Die Eiterungen im subumbilicalen Raume, Samml. klin. Vortr. n. F., Leipzig, 1894, p. 519.



the recti muscles, to have invaded the underlying peritoneum and to have extended, by an indurated stalk of tissue, to the vertex of the bladder. The tumor along with the involved portion of the peritoneum and the vertex of the bladder was removed. The patient made a good recovery from the operation. Schwarz pointed out that this was the first case reported of a primary adenocarcinoma developing in a urachus which had not primarily shown some pathologic condition, such as a cyst, or which had not remained patent for at least a short time after birth.

Michin's patient, a man of 64, entered the hospital complaining of urinary symptoms which had been present for two years. For one year he had noticed in the midline of the abdomen a tumor the size of a hen's egg. Cystoscopic examination showed a hemorrhagic ulcerated process projecting from the vertex of the bladder into the bladder cavity. The urine showed blood, pus and clumps of irregular epithelium which were thought to be carcinomatous in nature. A diagnosis of carcinoma of the bladder was made. At operation a thick-walled cyst was found resting on the vertex of the bladder to which it was quite adherent. The tumor along with the vertex of the bladder was removed. The patient made a good recovery from the operation. Macroscopic and microscopic examination of the neoplasm showed it to be a cyst of the urachus with malignant changes in its walls. Michin, just as Koslowski had done, thought that the presence of true gland elements in his tumor warranted the presumption that it had originated from some embryonic remains of the omphalomesenteric duct, but all those who have since that time discussed his case have considered that both it and Koslowski's started from the epithelium of the urachus.

In 1914 Pendl<sup>16</sup> reported what he thought to be the first instance described of a carcinoma arising from a urachal cyst. He, however, was not entirely correct in this claim, for Michin<sup>17</sup> had antedated him by two years by a report of his case which was of exactly the same type, although the latter had probably incorrectly considered his case to be one of a tumor arising from the omphalomesenteric duct. Pendl, in fact, in his article mentions besides his own only two other cases of solid urachal tumors, namely, those of Hoffmann and Schwartz. His patient, a man of 45, entered the hospital complaining of severe pains in the hypogastrium, polyuria and dysuria. On examination a cystic tumor was found extending from a little below the navel nearly to the symphysis. At operation this tumor was found to have grown tightly to the fascia of the muscle above it, while below it was firmly adherent

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16. Pendl, Fritz: Gallertkrebs einer Urachuscyste, Beitr. z. klin. Chir. **91**:681, 1914.

17. Michin (footnote 15, second reference).

the oldest was a man of 82 with an adenocarcinoma of the urachus and secondary involvement of the bladder.

3. These tumors have been found more frequently in men than in women. In this series the sex of the patient was not recorded in three cases; in three the patients were women, in fourteen men.

4. In Doran's, Michin's, Pendl's and Cullen's cases the solid tumors developed in the walls of urachal cysts. In Hoffmann's, Fischer's and Goebel's cases malignant growths originated in a urachus that had remained at least partially patent from birth. Goebel's case is especially interesting because a *Bilharzia* infection probably played a part in bringing about the malignant changes in the patent urachus. In the other fourteen cases of urachal tumors we know of no etiologic factors connected with the formation of these growths.

5. These tumors have caused the following symptoms: pain in the middle of the lower abdomen and, when the bladder has been involved, dysuria, polyuria and hematuria. Four patients discovered lumps in the abdominal wall before they experienced any trouble from them. Nuboer's case was unique in that his patient complained of pain in the left arm due to a distant metastasis before the primary growth had given any symptoms or had been noticed by the patient.

6. Eighteen of the reported cases have been malignant, two benign. In nineteen cases the growths arose primarily in the urachus. In one case (Rotter's) a primary papillary adenocarcinoma of the bladder extended to, and secondarily involved, a patent urachus.

7. Of the eighteen malignant tumors, seven were sarcomas, eleven were carcinomas. One of the carcinomas (Hoffmann's case) was squamous in type, the other ten were adenocarcinomas. Pendl and Khaum further describe their cases of adenocarcinoma as being colloid in character.

8. In fourteen of the eighteen cases of malignant urachal tumor, the bladder had already been invaded by the growth when the patient consulted a physician. Whenever this had occurred, there was a broad band of induration extending from the lower pole of the tumor to the vertex of the bladder at the point where the median abdominal ligament (the remains of the urachus) joins that organ. In six instances only the outer coats of the bladder were involved; in eight, cystoscopic examinations showed carcinomatous masses projecting from the vertex into the cavity of the bladder.

9. The tumor in Cullen's case, which must have been a true malignant urachal growth since it was attached by a definite pedicle to the vertex of the bladder, had not invaded the anterior abdominal walls. In all the rest of the cases, at least some invasion of the recti muscles and their fascias had occurred.

10. In only four cases of malignant urachal tumors was the peritoneal cavity found to have been invaded by the growth. Hoffmann's patient, on whom no operation was performed, died suddenly as the result of a perforation of the properitoneal carcinoma into the peritoneal cavity. Frank's patient, a boy of 11, was found at operation to have metastatic sarcomatous nodules in the omentum. The peritoneum beneath the growth, in Schwarz's case, was invaded by the urachal tumor which was an adenocarcinoma, while in Cullen's case, besides a multilocular cyst, which had undergone carcinomatous degeneration, there were metastatic nodules over the pelvic peritoneum.

11. A radical operation was performed in twelve of the malignant cases, in four the condition was too far advanced for surgery to offer any hope of relief. Smith does not record whether or not he operated on his two cases of urachal sarcomas. In seven cases in which a radical exsection of the malignant tumor was carried out, the vertex of the bladder was removed. Cullen's case is the only one in which not even a small part of the recti muscles were removed. Villa removed the whole hypogastric portion of the recti muscles from his patient.

12. Three of the patients with malignant tumors who were operated on died within a few weeks after the operation; Cullen's patient, one year later. The other eight patients are said to have made a good recovery from their operations. Villa and Klopp, however, are the only two surgeons who give any further history of their cases, their patients both being well eighteen months after they had been operated on.

13. It is often difficult to be sure that one is dealing with a malignant tumor of the urachus and not with an inflammatory condition of the anterior abdominal wall due to infection of urachal remains or of urachal cysts. Cullen,<sup>6</sup> in his book on the umbilicus (chapter XXXIII), gives in detail his case of abscess of the anterior abdominal wall arising from urachal remains and summarizes several other such cases reported in the literature. In inflammatory conditions pain is apt to be the first symptom and fever and night sweats soon develop. Malignant growths are frequently accidentally discovered by the patient before they produce any symptoms. As secondary infection, however, not infrequently occurs in malignant urachal growths, the absolute diagnosis between these two conditions can often not be made until after microscopic study of the tissue removed at operation.

14. My case was one of benign fibromyoma which had arisen from the sheath of the urachus. There is no history to suggest that the patient's urachus had remained patent in infancy or was at least of the urachus present. In the medical literature I have been unable to find any other case of benign urachal tumor reported as such.

agree, however, with Doran and Cullen that Aveling's tumor was really a benign fibromyoma of the urachus instead of a sarcoma, as he supposed it to be.

15. My study of malignant urachal tumors has impressed me with the fact that these growths occur more frequently than had previously been supposed, and that to cure these cases a very radical operation must be performed, usually including removal of the vertex of the bladder and portions of the anterior abdominal walls.

# PRIMARY MALIGNANT TUMORS OF THE LONG BONES

END-RESULTS IN ONE HUNDRED AND SEVENTY OPERABLE CASES

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AND

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NEW YORK

*Continued from page 876*

## REPORT OF CASES

**CASE 1.**—*Recurrent spindle cell sarcoma of tibia; amputation tried by other surgeons; treated with toxins alone; patient well, with a normal limb, at present, twenty-six and one-half years later.*

W. F., a man, aged 27, first noticed a swelling of the left tibia at the junction of the middle and upper thirds in March, 1897; this slowly increased in size until July 28, he was operated on by Dr. Stewart of Toronto, Canada. A prompt recurrence took place and, November 25 of the same year, a second operation was performed, consisting in incision and curetting of the bone; the tissue was sent to Dr. John Caven, professor of pathology, University of Toronto, who pronounced it a spindle cell sarcoma. The tumor again recurred, and the patient was referred to us for toxin treatment in February, 1899.

Physical examination at this time showed a tumor at about the junction of the middle and upper thirds of the left tibia, measuring 3 by 4 inches (7.6 by 10.1 cm.), with an ill defined border; over the central portion were two ulcerations the size of a silver quarter. The patient was admitted to the Memorial Hospital where the mixed toxins of erysipelas and *Bacillus prodigiosus* (Coley) were begun at once and continued for about two months. The tumor rapidly disappeared and the bone cavity healed with healthy granulations. Before the healing process was entirely completed, the patient contracted a second attack of accidental erysipelas (a patient with a fresh case of erysipelas had been in the ward not long before), which ran the usual course of about six days. Healing continued rapidly and was completed two or three weeks later, after which the patient returned to his home in Canada. At the present time, twenty-six and one-half years later, he is in excellent condition with a normal, functional leg, and is able to attend to his duties as a farmer.





Fig. 1.—Myositis ossificans of femur simulating periosteal sarcoma.



Fig. 2.—Syphilitic osteitis of radius closely simulating sarcoma.

not only the head of the humerus, but the tip of the coracoid and part of the glenoid cavity as well. An inter-scapular thoracic amputation was advised but refused. No attempt was made to remove the entire tumor at operation. The patient was immediately put on the mixed toxine of erysipelas and *Bacillus prodigiosus*, and the treatment was carried out under my direction. She made a complete recovery with full restoration of function, and remained in excellent health until 1921, or twenty-two years later, when she developed what was



Fig. 3.—Periosteal osteogenic sarcoma of femur after one year of radium and roentgen-ray treatment; the ivory-like appearance of the bone above the tumor, with resulting pathologic fracture, should be noted.

believed to be a metastatic tumor of the spine, which caused her death in a few months.

The original slide of the tumor, which was removed at the Boston City Hospital in 1899, was not preserved, so it is impossible to verify the diagnosis of round cell osteosarcoma which was made by Dr. F. B. Mallory, professor of pathology, Harvard Medical School.

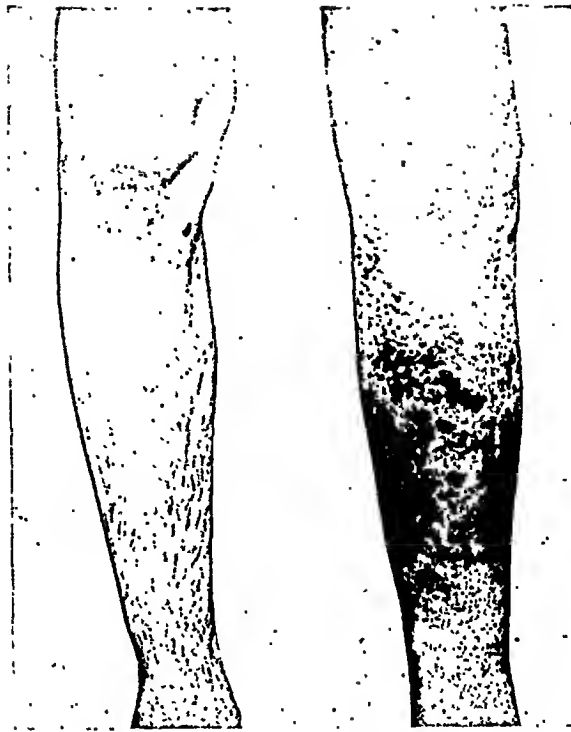


Fig. 4 (case 1 in text).—Periosteal spindle cell sarcoma of shaft of tibia; recovery under prolonged toxin treatment followed by attack of accidental erysipelas; patient well twenty-eight years later.

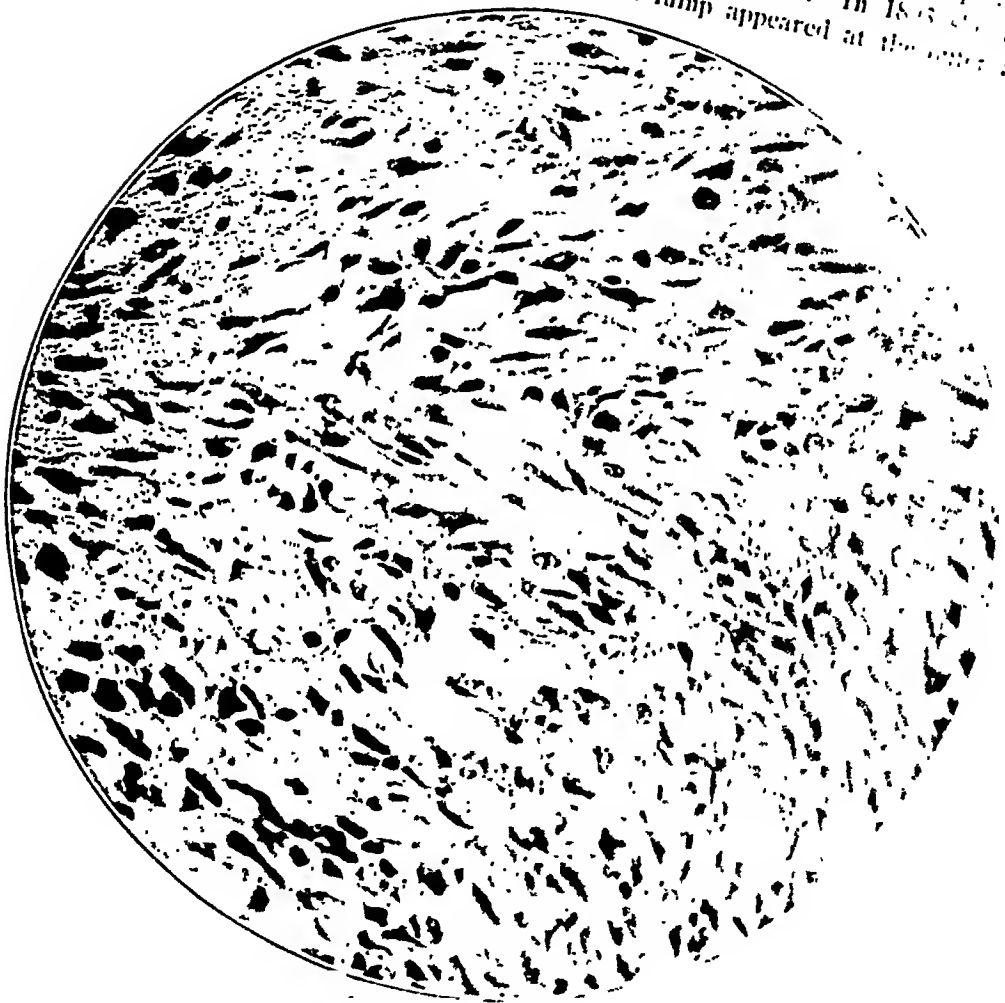


Fig. 5 (case 4 in text).—Small round cell periosteal sarcoma involving two thirds of shaft of femur with metastases. The patient recovered under toxin treatment, and has been well for ten years.

## COLEY-COLEY-TUMORS OF LONG BONES

CASE 3.—Three times recurrent spindle cell sarcoma of metatarsal bone; amputation followed by toxins; inoperable; disappearance under toxins; patient well twenty-nine years later.

F. K., a girl, aged 16 years, fell in 1888, injuring her right foot; shortly after a swelling appeared in the region of the injury and grew steadily until 1891, when the patient was operated on by Dr. William T. Bull at the New York Hospital. Three years later she received another injury to the foot, which was followed by a prompt recurrence. A Symes amputation was then performed by Dr. Bull. In 1893 she fell down stairs, injuring the stump; shortly after, a lump appeared at the outer aspect of



and kept up with occasional intervals of rest for three years. The tumor disappeared; there was no further recurrence, and the patient was in excellent condition when last examined, twenty-nine years later.

**CASE 4.**—*Periosteal round cell sarcoma of femur, involving two thirds of shaft, with extensive multiple metastases; apparent cure by the mixed toxins of erysipelas and Bacillus prodigosus; well ten and one-half years, when a malignant tumor (sarcoma and epithelioma) developed in the thigh at the site of an old roentgen-ray dermatitis.*<sup>21</sup>

A. G., a man, aged 19, was referred to us in February, 1902, with a small round cell sarcoma involving two thirds of the shaft of the femur. The diagnosis had been confirmed by microscopic examination of Prof. E. K. Dunham, Bellevue Hospital Medical College. The involvement was so extensive that we advised an

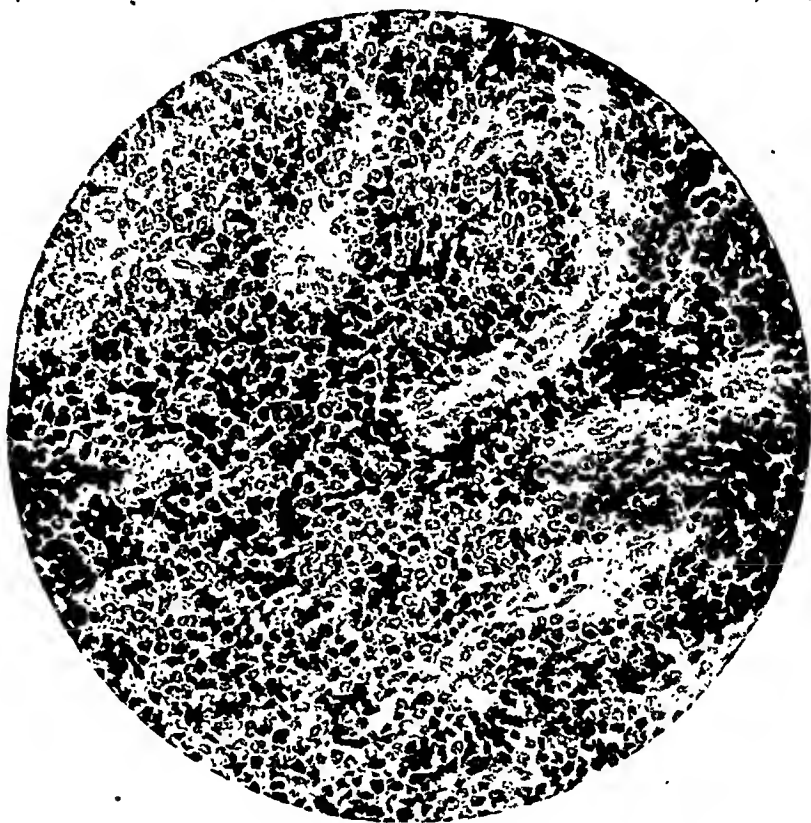


Fig. 7 (case 8 in text).—Periosteal sarcoma of femur.

immediate amputation; this the patient refused. During prolonged roentgen-ray irradiation an extensive metastatic tumor developed in the left pectoral region; this was removed surgically and the roentgen rays resumed. A second and larger metastatic tumor, the size of a child's head, appeared in the ilio-lumbar region, involving the ilium. This was treated by toxins alone; under six weeks' injections, it broke down and drainage was established by an incision made through the upper and posterior part of the ilium. The patient made a complete recovery with the exception of a persistent dermatitis which followed the irritation from the roentgen rays, in the lower and anterior portion of the thigh. At the end of ten and one-half years this dermatitis suddenly took on signs of malignant degeneration; amputation was performed, Jan. 2, 1913; about two weeks later, the patient developed metastases in the lung and probably also in the peritoneum, and died January 16.



followed by prophylactic toxin treatment was advised. An amputation 4 inches (10.1 cm.) below the trochanter was performed by Dr. Erdman, and the patient was then referred to us for toxin treatment. The injections were begun in September, 1906, and kept up for four months. The patient made a good recovery, and has remained in excellent health up to the present time, eighteen and one-half years later.

A microscopic examination was made by Dr. F. E. Sondern, who reported round cell periosteal sarcoma. The slide in this case was later lost, so that it was impossible to register the case in the Bone Sarcoma Registry.

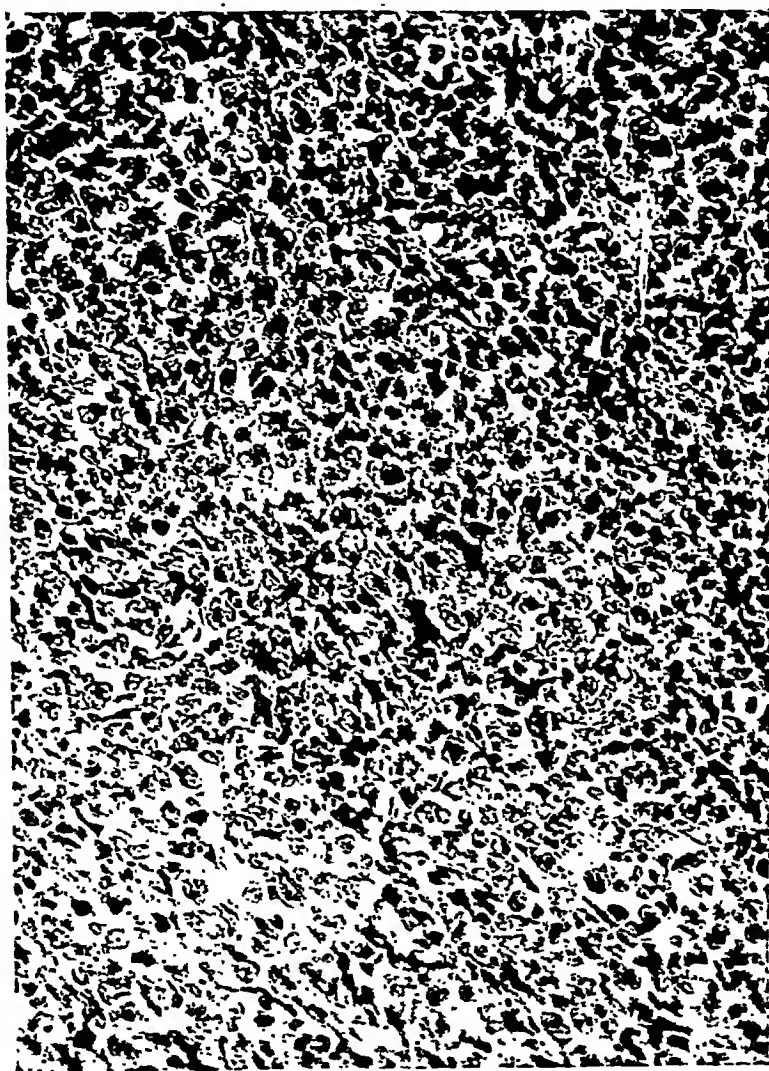


Fig. 9 (case 15 in text).—Osteogenic sarcoma of shaft of tibia with metastases in inguinal and iliac glands; radium and prolonged toxin treatment; limb saved; patient well nine years later.

*CASE 6.—Periosteal osteogenic sarcoma of femur; amputation followed by toxins one year; well eighteen years.*

Mrs. S., a married woman, aged 40, had always been well until the spring of 1908, when while dancing on a hard floor at St. Moritz, Switzerland, she slipped and fell, injuring her right knee; pain developed shortly afterward, and in a few weeks the leg had greatly increased in size. She was first seen by us in consultation with Dr. A. D. Bevan of Chicago in the fall of 1908.

Physical examination at this time revealed a swelling of the lower end of the femur, firm in consistency but not of bony hardness; the knee joint was not involved. Roentgen-ray examination showed a tumor apparently of periosteal origin. The clinical and roentgen-ray diagnosis was sarcoma.

In view of the rapid growth and the extent of the involvement, we concurred in the opinion of Dr. Bevan that an immediate amputation should be performed; this was done in November, 1908. A microscopic examination was made by the



Fig. 10 (case 15 in text).—Five years after treatment.

pathologist of the Presbyterian Hospital, Chicago, and his diagnosis was periosteal osteogenic sarcoma. The diagnosis was confirmed by Ewing, and the case registered in the Bone Sarcoma Registry. As soon as the wound had healed the patient was put on the mixed toxins of erysipelas and *Bacillus prodigiosus*, and this treatment was continued by Dr. Lull of Oak Park, under our direction, for nearly a year. The patient was rather susceptible to the toxins and could never take more than 5 minims, which produced a fairly marked reaction.



The patient made a complete recovery and is well at the present time, seventeen years later.

*CASE 7.—Recurrent periosteal osteosarcoma of humerus; treated by toxins and roentgen ray; limb well at present, eighteen years later.*

We are indebted to Dr. John H. Gibbon, Philadelphia, for the following report: I. R., a girl, aged 17 years, was admitted to the Jefferson Hospital, Feb. 14, 1908. On the following day an operation was performed by Dr. Gibbon, who found a



Fig. 11 (case 15 in text).—Section from inguinal node; metastatic sarcoma.

periosteal sarcoma with considerable infiltration of the muscular tissue; the whole mass was incised, the thickened periosteum was chiseled away, and the wound was left open with the intention of using roentgen-ray and toxin treatment in the event of amputation being refused. The patient was willing to have the amputation performed but her family would not consent to it.

The microscopic report of the pathologist of the Jefferson Hospital was that the growth was an osteosarcoma, with spindle cells predominating. A later microscopic report by Ewing stated: "The sections are quite small, being 10 by 1 mm. They show what appears to be a fibrosarcoma of periosteal type, but a positive

diagnosis is hardly warranted on account of the small size of the tissue examined. There is generally more stroma than cells, except in one focus where the cells are more numerous."

Examination, March 6, 1908, showed a distinct local recurrence involving the muscles. The patient was put on the mixed toxins supplemented by roentgen rays. Under the combined treatment the recurrence entirely disappeared, and the patient was shown before the Interurban Orthopedic Club, Nov. 4, 1910, in excellent condition. A recent letter from Dr. Gibbon states that the patient is still well, seventeen years later.<sup>22</sup>

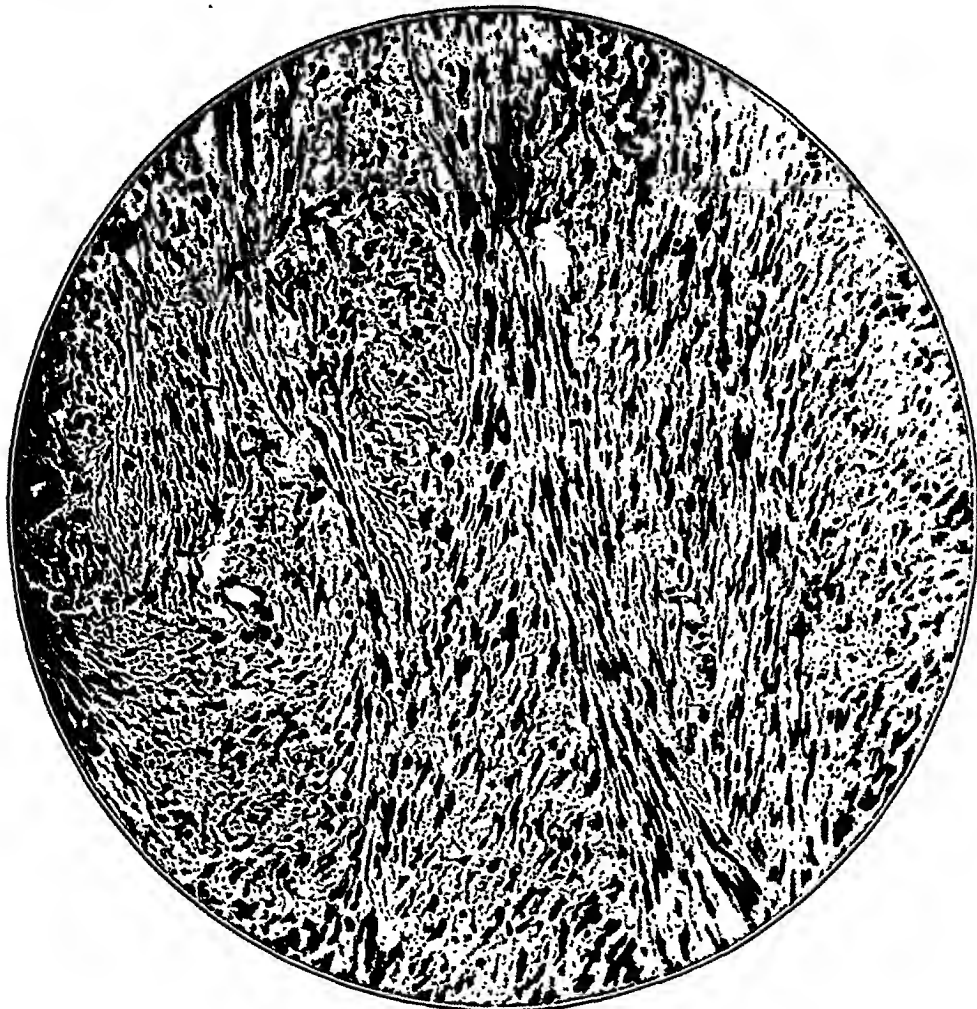


Fig. 12 (case 17 in text).—Periosteal osteosarcoma; no improvement under toxins and radium; amputation followed by toxins; well more than nine years later.

CASE 8.—*Periosteal sarcoma of femur; endothelioma; patient well sixteen years.*

This case is case 1 in Connor's article on endothelial myeloma, *ARCHIVES OF SURGERY*, April, 1926.

H. J., a man, aged 22, was operated on by Dr. John A. Hartwell at the Presbyterian Hospital in October, 1909, for a tumor of the femur. The microscopic report was round cell sarcoma. In December, 1909, he was referred to us

22. This case was reported in *Ann. Surg.* (Tr. Philadelphia S. Soc.), February, 1910, and also in the Bone Sarcoma Registry.

by Dr. Joseph A. Blake for toxin treatment, in the hope of saving the limb. Slight temporary improvement was noted, but a recurrence later took place, and we advised an immediate hip joint amputation, which was performed by Dr. Blake, December 23.

The microscopic report was: "The tumor is composed of medium size round cells packed together and supported by very little stroma. The tumor is vascular; the blood vessels lie in intimate contact with the cells; the cells radiate from the walls of the blood vessels in a manner that suggests their having originated from them. There are large spaces in the tumor which contain necrotic tissue and leukocytes. The diagnosis is round cell sarcoma (perithelioma)."



Fig. 13 (case 18 in text).—Periosteal osteogenic sarcoma of femur; amputation; postoperative toxins; patient well nine years.

The patient was again referred to us and received two periods of prophylactic toxin treatment at the Memorial Hospital during the winter and following spring. There has been no return of the tumor and the patient is in excellent condition at the present time, sixteen years later.

This case was reported in the Bone Sarcoma Registry under the Presbyterian Hospital series of cases. Ewing has recently reviewed the slide of the case and pronounced it an endothelioma.

*CASE 9.—Periosteal sarcoma of femur (clinical and rocutgen-ray diagnosis); probably of the endothelioma type; recovery under toxins alone; well twelve years.*

This case is reported in full in *Annals of Surgery*, March, 1913.

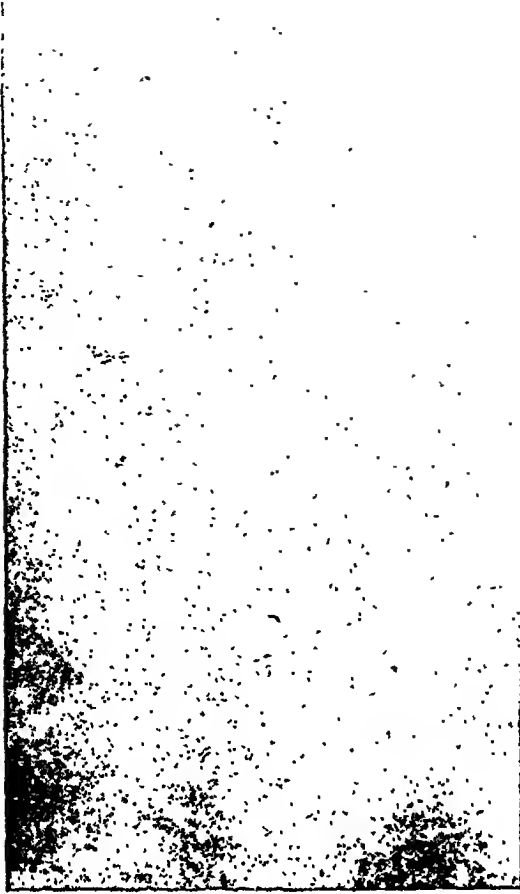


Fig. 14 (case 19 in text).—Inoperable periosteal sarcoma of femur involving two thirds of shaft (1917); clinical and roentgen-ray diagnosis.



Fig. 15 (case 19 in text).—One year later than figure 14 after eight months' toxin treatment and one radium treatment.

Mrs. G. M., aged 27, had considerable tuberculosis in her family history. In May, 1912, the patient first felt pain in the right femur; this was treated for rheumatism for two months. Shortly after this a swelling developed at the same site, which slowly increased in size; there were no temperature and no signs of inflammatory trouble.

Physical examination at the time of our first observation, Sept. 19, 1912, showed a hard, fusiform enlargement apparently of bony origin occupying the upper and middle thirds of the right femur, gradually shading off into the normal outline of the bone; the tumor measured 8 by 7 inches (20.3 by 17.7 cm.); and at its largest circumference it measured  $19\frac{1}{4}$  inches (48.8 cm.). The skin was normal. There was no vascular dilatation.

The patient had been examined by four surgeons, all of whom agreed on the diagnosis of periosteal sarcoma, and all of whom advised an immediate hip joint amputation. Although we concurred in the diagnosis, we believed it justifiable to



Fig. 16 (case 19 in text).—Seven and one-half years later than figure 15; patient now well eight and one-half years after treatment.

await the result of a brief course of toxin treatment before resorting to amputation. In order to verify the diagnosis, we performed an exploratory operation, Sept. 20, 1920; on cutting through the muscle we found a tumor apparently of periosteal origin, about three-fourths inch (1.8 cm.) thick; dissection revealed no evidence of pus or inflammatory tissue; the latter was mostly white, firm in consistency, and had all the typical macroscopic appearances of a periosteal sarcoma with little or no new bone formation. A microscopic examination was made by Ewing, who reported "the tissue shows very little if any specific process and does not permit of diagnosis. There is infiltration of the vessels with large round cells suggesting sarcoma, but which might very well be tuberculous." This same difficulty in making a positive diagnosis from microscopic sections had been noted in at least four of our cases which later proved to be sarcoma (endothelioma type).

The patient was immediately put on the mixed toxins of erysipelas and *Bacillus prodigiosus* without other treatment. The tumor at once began to decrease in size. Three months later the patient's condition was about the same; if anything, there was slight decrease in size of the tumor. A sinus persisted at the point of the original incision. While the patient showed no marked decrease in the circumference of the thigh, her weight increased a pound a week. The toxins were continued about six months.

Roentgen-ray examination made in March, 1913, showed the bone apparently much more dense than at the time of the previous examinations, as though the tumor tissue had been replaced by normal bone. By September, 1913, the patient



Fig. 17 (case 20 in text).—Periosteal sarcoma of tibia; diffuse endothelioma (Ewing); well eight years after amputation followed by prolonged toxin treatment.

had gained 21 pounds (9.5 Kg.) in weight. The measurements were the same on both sides; her general condition was excellent, and she had no pain. The patient was in excellent condition when last traced, twelve years later.

Here we believe that the clinical, roentgen ray and microscopic evidence point almost conclusively to a diagnosis of endothelial type of tumor of the shaft of the femur. It is interesting to note that the disease was completely controlled by the toxins alone without radiation. The clinical history, roentgengram and macroscopic appearance of the tumor on exploratory operation closely resembled other cases of the endothelioma type of sarcoma of the long bones.



Fig. 18 (case 21 in text).—Metastasis to skull following amputation for periosteal sarcoma of femur one and a half years before.

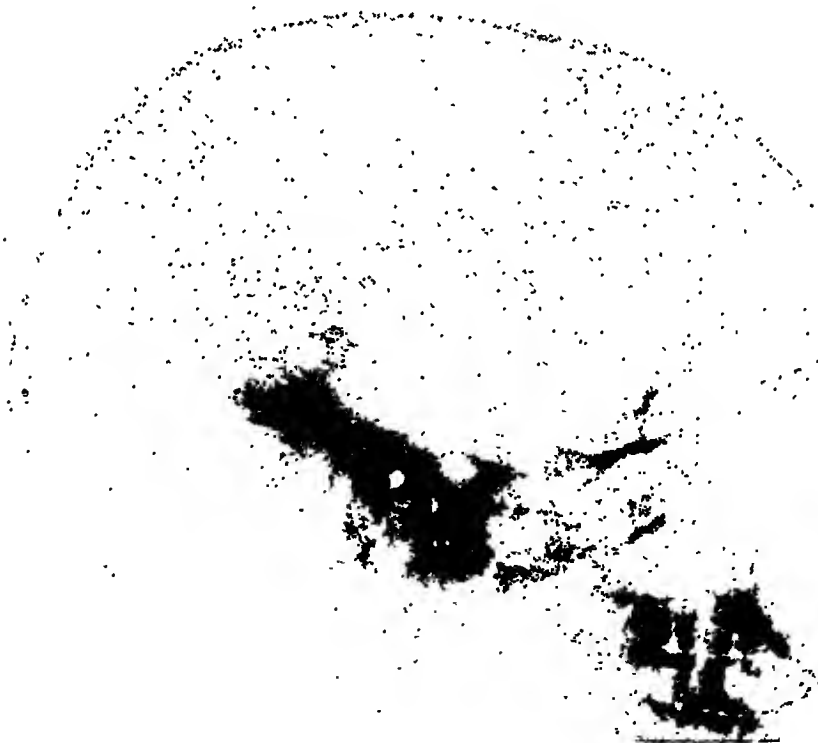


Fig. 19 (case 21 in text).—Four years later than figure 18; marked regeneration of bone. The patient is now well, seven and one-half years later.

CASE 10.—*Periosteal osteogenic sarcoma of femur; amputation followed by prolonged prophylactic toxin treatment; patient well twenty years later.*

S. D., a girl, aged 18 years, had a negative family history. In the beginning of 1905, the patient first noticed pain in the right knee; this continued until August of the same year, when a plaster splint was applied at St. Luke's Hospital. The condition at that time was regarded as of tuberculous origin. The splint was worn for nearly seven months. March 29, 1906, the patient was admitted to the Hospital for Ruptured and Crippled, in Dr. V. P. Gibney's service. During the preceding two months she had been confined to bed and was in an emaciated and extremely weak condition.

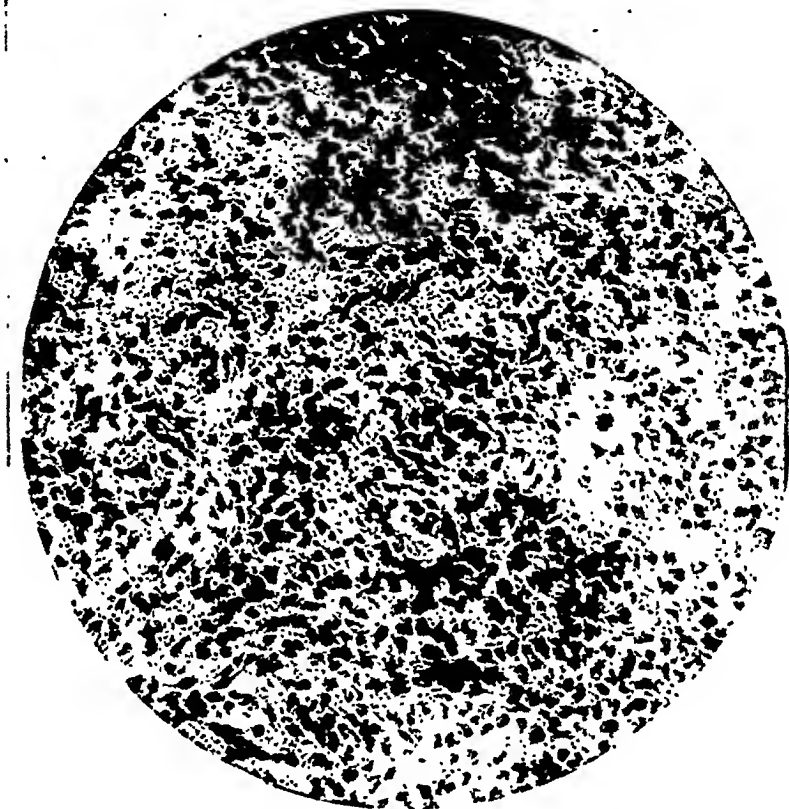


Fig. 20 (case 21 in text).—Specimen classified as endothelioma by Ewing and as round cell sarcoma by other pathologists; patient well nearly seven years later.

Examination of the right knee showed a fusiform swelling just above the joint; the circumference of this knee was nearly 5 inches (12.7 cm.) greater than that of the opposite one. Roentgen-ray examination at this time showed the lower 6 inches (15.2 cm.) of the femur nearly twice the normal thickness.

An exploratory operation was performed by Dr. Gibney and one of us, revealing what was believed to be a sarcoma. In view of the extent of the involvement an immediate amputation was advised, and performed 4 inches (10.1 cm.) below the trochanter, April 7. The patient was then put on the mixed toxins, the injections being increased up to the point of producing marked reactions. She almost immediately began to gain in weight, rising from 69 pounds (31.3 Kg.). June 12, to 92 pounds (41.7 Kg.). October 24. She has remained in good health up to



the present time, and was shown before a special bone clinic at the Memorial Hospital in April, 1925, nineteen years later.

The diagnosis made by Dr. Jeffries, pathologist to the Hospital for Ruptured and Crippled, in this case was osteosarcoma, mixed cell (no giant cells). The slide has been recently reviewed by Ewing and pronounced malignant osteogenic sarcoma. The case has been registered in the Bone Sarcoma Registry.

CASE 11.—*Periosteal sarcoma of ulna; amputation followed by toxins; patient well seventeen years later.*



Fig. 21 (case 12 in text).—Periosteal sarcoma of fibula; endothelioma; extensive metastases to femoral, iliac and inguinal glands as well as to lung; amputation followed by toxins and radium; patient well six years later.

E. M. I., a boy, aged 15 years, with a negative family history, early in July, 1908, came under the care of Dr. Robert M. Lovett, Boston, with the history that he had slipped on an oiled floor in the school room, fracturing and dislocating the elbow; this was reduced two hours later; four days later the arm was reset. Seven months later he began to have pain at the site of the fracture; a tumor developed and grew rapidly. Roentgen-ray examination showed an extensive tumor of the upper half of the ulna. An amputation of the arm was performed by Dr. Lovett in July, and the patient was immediately referred to

us for toxin treatment. The injections were carried out at home by the local physician under our direction; they were given every other day for a period of three months; the final dose,  $5\frac{1}{2}$  minims, was given October 9; a severe reaction followed. The patient has remained in good health up to the present time, seventeen years after the amputation was performed.

A microscopic examination was made by Dr. Whitney of the Harvard Medical School, who reported round cell sarcoma. Since Dr. Whitney's death his specimens have been scattered and it has been impossible to obtain a slide for verification of the diagnosis. This case has been registered in the Bone Sarcoma Registry as a giant cell sarcoma, but the clinical history and the roentgenograms, together with



Fig. 22 (case 22 in text).—Metastases in lung.

Dr. Whitney's microscopic report, incline us to believe that it should be classed as a sarcoma of the endothelioma type.

*CASE 12.—Periosteal spindle cell sarcoma of the right forearm and radius.*

K. W., a girl, aged 16 years, was referred to us by Dr. George H. Monks, Boston, April 7, 1913, with the history that five years before the patient had twisted her right forearm violently while at play; one year later a swelling appeared 2 inches (5 cm.) above the wrist joint. During the next year she received a short course of roentgen-ray irradiation at the Massachusetts General Hospital. The tumor continued to increase in size, and she was seen by Dr. Monks in January, 1913, when a diagnosis of sarcoma was made, and amputation advised. The tumor at that time was  $9\frac{1}{2}$  inches (24 cm.) at its greatest circum-

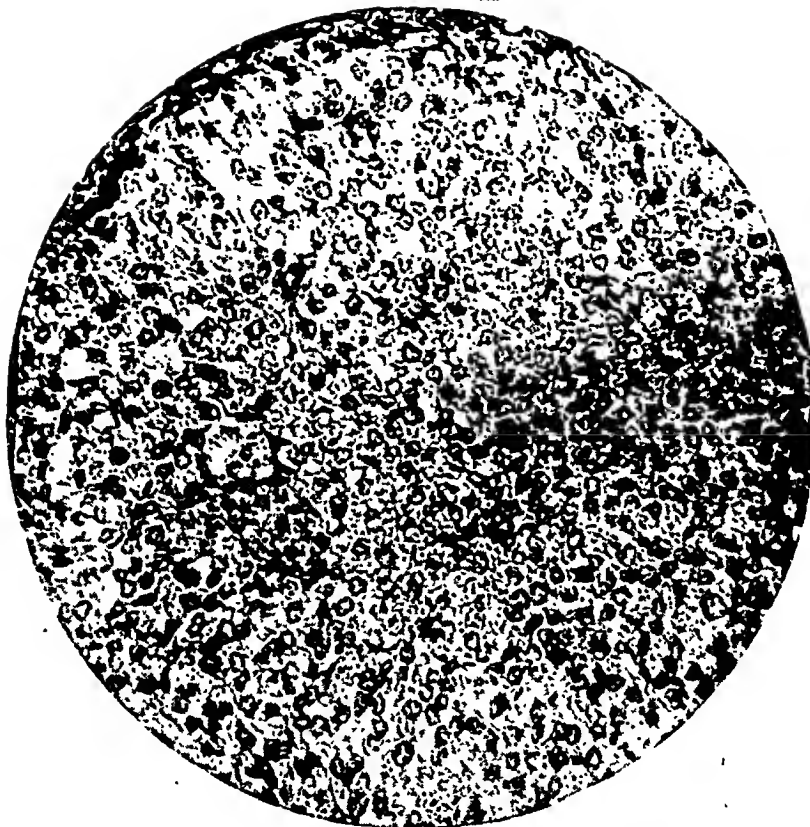


Fig. 23.—Specimen from case 12 in text.



Fig. 24 (case 24 in text).—Sarcoma of tibia. Amputation was performed and toxins were given. The patient was well five years later.

ference, and apparently involved the lower portion of the radius and ulna; it was uniform in contour and slightly tender over its entire surface, with occasional areas in which an indefinite sense of fluctuation could be made out. She was treated for three months at Grace Hospital, without improvement, and later was treated at the Homeopathic Hospital for nine weeks, without improvement.

Physical examination at the time of our first observation showed a fusiform swelling of the lower end of the ulna and radius, beginning at  $1\frac{1}{2}$  inches (3.7 cm.)



Fig. 25 (case 24 in text).—One month later than figure 24.

above the lower end of the radius and extending up 5 inches (12.7 cm.), entirely surrounding the forearm. Extension of the fingers was limited; the skin was markedly discolored.

The patient was put on the mixed toxins; twenty injections in all were given, two-thirds systemically and one-third locally. There was no improvement. A roentgen-ray examination was made by Dr. A. F. Holding, who reported sarcoma, apparently periosteal, of the ulna, and deformity and atrophy of the radius. In view of the roentgen-ray and clinical observations, we decided that it was unwise to try conservative treatment any longer, and therefore, May 5, 1913,

we amputated the arm at the upper third. The toxins were resumed after the operation, and were given for a considerable period of time at home.

The microscopic diagnosis of Ewing was periosteal spindle cell sarcoma. The case is registered in the Bone Sarcoma Registry.

The patient made a good recovery, she gained considerably in weight, and was in excellent condition with no evidence of a recurrence when last heard from, thirteen years later.

CASE 13.—*Sarcoma of humerus*. M. K., a man, aged 51, with a negative family history, had no history of trauma. He had the ordinary diseases of child-

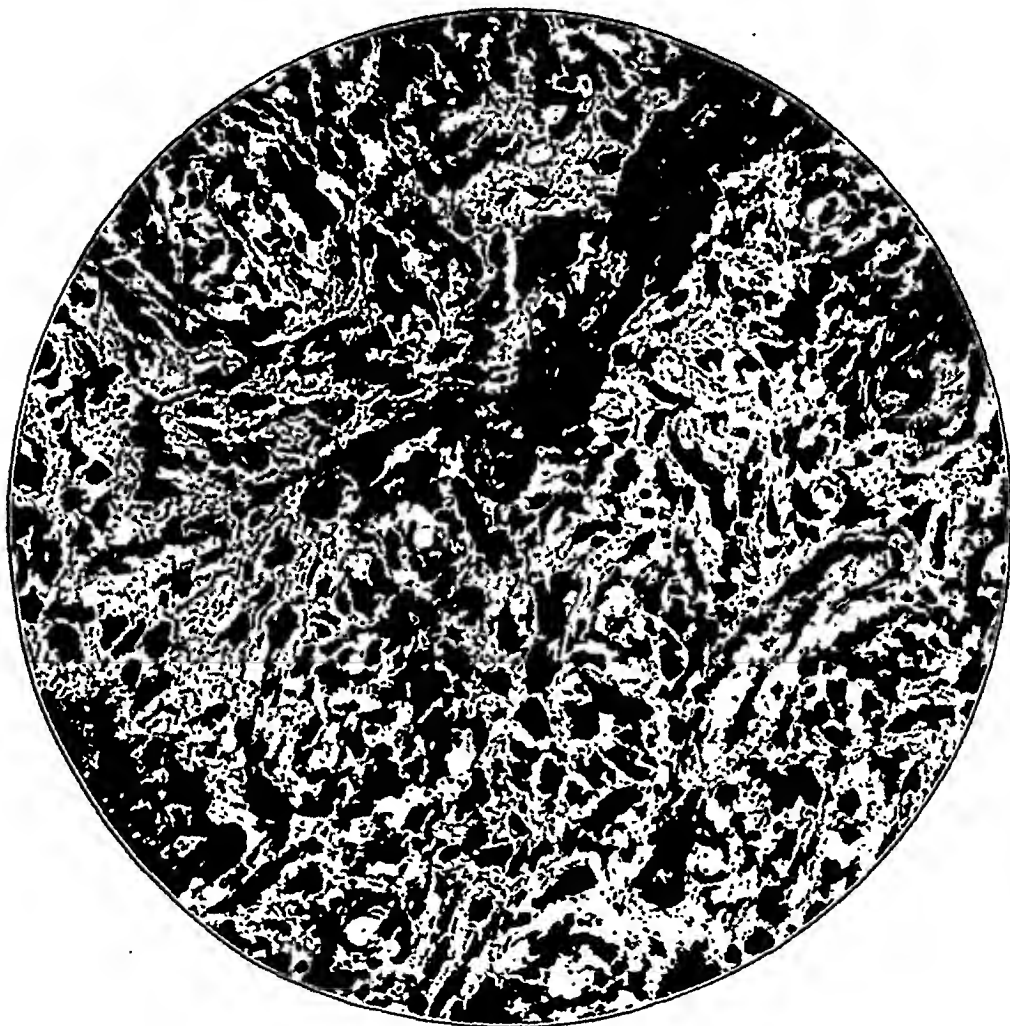


Fig. 26 (case 24 in text).—Sarcoma of tibia.

hood; had gonorrhea at 31, but no history of syphilis. In 1913 the patient was admitted to the Nassau County Hospital, where a suprapubic operation was performed on account of an attack of retention of urine; this was accompanied by a high fever, during which the patient's right arm suddenly became paralyzed; he was in bed for eighty-one days. April 12, 1915, the patient was admitted to the Memorial Hospital, to the service of Dr. W. A. Downes. He was treated for a year and a half with roentgen-ray irradiation for a condition of the right shoulder which was supposed to be sarcoma, based on the clinical diagnosis of Dr. L. A. Stimson, and supported by roentgen-ray examination. The condition slowly improved. After leaving the Memorial Hospital, the patient developed a

roentgen-ray burn over the shoulder; this resisted all palliative treatment. He was admitted to the City Hospital, April 18, 1917, where he was operated on by Dr. Nathan W. Green, who resected the head of the humerus, head of the scapula and outer end of the clavicle. The wound was slow in healing on account of the traumatism caused by the roentgen-ray therapy.

The microscopic diagnosis of Dr. Larkin of the Strecker Memorial Laboratory was small spindle cell sarcoma.

The patient made a good recovery, and in a letter dated January, 1925, he wrote that he was in excellent condition.



Fig. 27 (case 26 in text).—Periosteal osteogenic sarcoma of femur; popliteal region; amputation plus toxins; well five years.

The peculiar early clinical history lends itself to the possibility that the original trouble in the humerus was an osteitis or osteomyelitis and that the sarcoma found at the operation one and one-fourth years later developed on the old roentgen-ray burn.

*CASE 14.—Periosteal spindle cell sarcoma of the metatarsal bone; amputation followed by prophylactic toxin treatment; patient well when last traced, ten years later.*

E. W. M., a woman, aged 22, with a negative family history had no definite history of injury. In June, 1901, the patient first noticed pain, and a slight swell-

ing in the dorsum of the right foot developed soon after. The pain increased in severity, requiring morphine. She was treated for a number of weeks for rheumatism. One of us first saw her in consultation with Dr. Alexander Lambert in August, 1901. The clinical diagnosis was periosteal sarcoma. An immediate amputation was advised, which, three days later, one of us performed at the junction of the middle and lower thirds of the tibia. On microscopic examination the tumor proved to be a spindle cell periosteal sarcoma. Shortly after the operation the patient was put on prophylactic toxin treatment which was kept up for eight months. Examination ten years later showed her in excellent condition with no evidence of a recurrence.

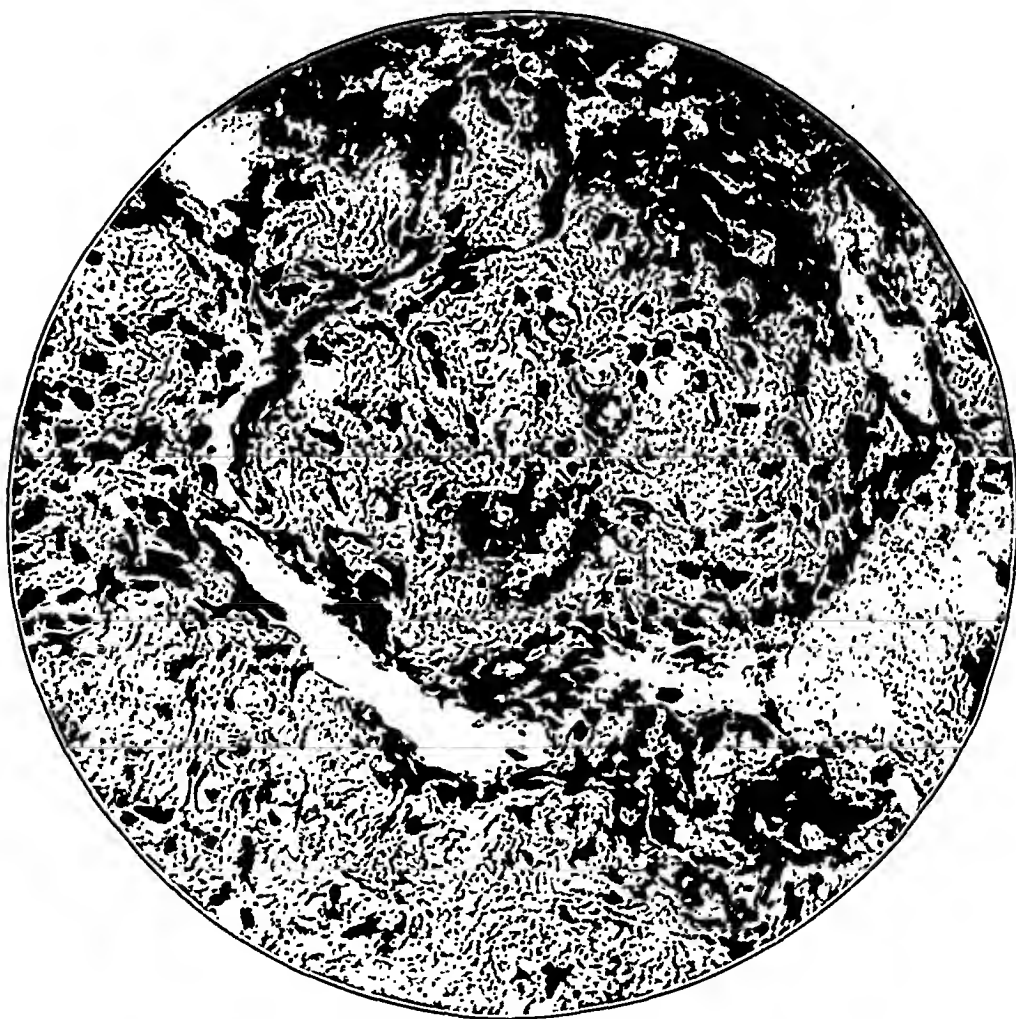


Fig. 28 (case 26 in text).—Periosteal osteogenic sarcoma of femur.

CASE 15.—*Periosteal osteogenic sarcoma of tibia with extensive inoperable metastases in the femoral, inguinal and iliac glands; complete recovery under toxins and radium treatment; limb saved; patient well nine years later.*

C. H. S., a man, aged 39, was referred to us by Dr. John H. Gibbon of Philadelphia in the latter part of April, 1917, with a history of a rapidly growing tumor of the shaft of the left tibia of six weeks' duration. Dr. Gibbon and several other surgeons regarded it as a periosteal sarcoma. We concurred in the diagnosis but in order to confirm it, we did an exploratory operation, removing a piece of the tumor. This was turned over to Dr. James Ewing for examination,

and he pronounced it a highly malignant osteogenic sarcoma. We decided to try conservative treatment for a while instead of amputating immediately, and started him on the mixed toxins of erysipelas and *Bacillus prodigiosus* combined with radium treatment. From May 1 to July 19 he received 46,720 millicurie hours of radium over the tibia. The toxins were kept up at home by his physician, Dr. R. G. Gamble. In the middle of August, the patient asked permission to go to the seashore for a month; as physical examination at this time failed to reveal any evidence of the disease remaining, we decided that it would do no harm to discontinue the toxins for a few weeks. The patient returned to us in the early part of October.



Fig. 29 (case 29 in text).—Sarcoma of upper end of humerus with metastases in lung, diagnosed clinically and by roentgen ray. Toxins were administered; the patient recovered, and has been well for six years.

Examination at this time showed extensive metastases in the inguinal, femoral and iliac glands, some of which were an inch (2.5 cm.) or more in diameter. We gave a hopeless prognosis but decided to try the treatment a little longer. The radium pack was applied over the glands of the groin in October (18,000 millicurie hours), in November (17,270 millicurie hours) and in December (12,000 millicurie hours). At the same time, the toxins were resumed and kept up with occasional intervals of rest for two and a half years, in doses not sufficient to interfere with the patient's daily routine of life. All evidence of the disease disappeared as shown by later roentgen-ray and physical examinations. The patient is alive



and well at the present time, July, 1926, with a useful limb, nine and a quarter years later.

This is one of the few cases on record of a periosteal osteogenic sarcoma with metastases that has been cured by any method of treatment; it has been included in the Bone Sarcoma Registry as one of the thirteen cases (up to October, 1924) of periosteal sarcoma in which the clinical, roentgen-ray and microscopic diagnosis has been passed on by the committee which has remained well for five years, and the only one in which the limb was saved.

*CASE 16.—Periosteal sarcoma of lower end of femur; treated with prolonged radiation and toxins, without control; amputation followed by prolonged toxin treatment; well nine years later.*



Fig. 30 (case 29 in text).—Four years after treatment; no metastases present.

W. P., a married woman, was admitted to the Memorial Hospital, Feb. 15, 1917. She had had a stiff knee for one year, and had lost weight. There had been gradual increase in size with almost complete loss of motion in the joint, until it was 1 inch (2.5 cm.) larger than normal in circumference. She consulted Drs. George E. Brewer and George D. Stewart of New York, both of whom advised an immediate amputation. She then consulted Dr. J. M. T. Finney of Baltimore, who advised radium; this treatment was carried out at Dr. Howard Kelly's Hospital at Baltimore by Dr. C. F. Burnam from Oct. 23, 1916, to January, 1917, as follows: Oct. 23, 1916, 3,308 mg. for fourteen hours; October 29, 934 mg. for seventeen hours; November 15, 3,364 mg. for eleven hours; November 29, 100 mg. for fourteen hours; December 14, 1,392 mg. for twelve hours, and Jan. 11, 1917, 618 mg. for thirteen and one-half hours.

There was little if any improvement from the radium. The patient returned to Dr. Finney in January, 1917, and he operated, chiseling a portion of the periosteum from the outer aspect of the femur. The diagnosis was periosteal sarcoma.

The wound healed by primary union and the patient was then referred to us for toxin treatment. For five months she was treated with injections of the mixed toxins supplemented by one radium treatment in the form of a pack (7,200 milli-curie hours at 5 cm. distance). There was little benefit noted and, July 6, 1917, we amputated the limb, following this with prophylactic toxin treatment.

On microscopic examination Ewing reported a periosteal osteogenic sarcoma of the sclerosing type.

The patient made a good recovery and has remained in excellent condition up to the present time, nine years later. This case was reported in the Bone Sarcoma Registry.

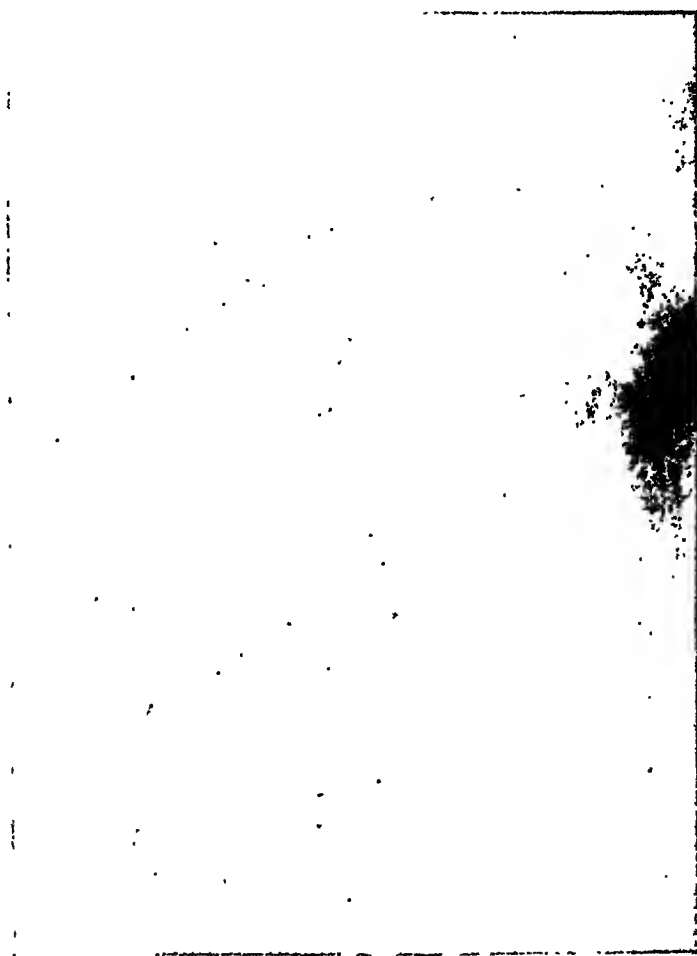


Fig. 31 (case 32 in text).—Extensive sarcoma of upper third of femur with marked destruction of bone (clinical and roentgen-ray diagnosis); probably endothelioma. Recovery was made under toxins alone; the patient has been well for five years.

CASE 17.—*Osteosarcoma of femur.* G. T., a woman, aged 26, with a negative family history, in May, 1915, fell, injuring her left knee. The next morning she noticed a small swelling on the outer part of the thigh; this remained unchanged during the following year. Feb. 24, 1916, she again fell, injuring the same leg, and soon after noticed a tumor on the inner side of the thigh near the knee; this steadily increased in size; it was not associated with pain.

Physical examination at the time of our first observation, June 20, 1916, showed a hard, bonelike tumor, beginning at the middle of the popliteal space

and occupying the whole posterior surface of the thigh, measuring 4 inches (10.1 cm.) in diameter and extending upward 5 inches (12.7 cm.). The tumor was extremely hard in consistency, markedly protuberant, and with broad attachment to the femur. The roentgenograms showed a typical periosteal sarcoma of the osteoid type occupying the posterior lateral surface of the femur just above the lower end. During the first three weeks of July, 1916, the patient was treated with systemic injections of the mixed toxins, seven in all, supplemented by the radium pack, 4,000 millicurie hours, applied over three different areas, July 4, and a similar treatment, July 9, making a total of 24,000 millicurie hours of



Fig. 32 (case 32 in text) —Femur at time of injury showing no tumor or pathologic condition.

radium. As there was no apparent improvement noticed under conservative treatment, we amputated the leg, August 20.

The microscopic report of Ewing stated: "The section shows a spindle cell sarcoma inclosing many well formed trabeculae of bone. The spindle cells are well formed, long, slender, and are supported by considerable fibrous stroma. The tumor is to be classed with the fibrosarcomas in malignancy, which appears to be much less than in the usual bone sarcoma." A previous report by Ewing, based on a microscopic examination of a specimen removed on exploratory incision, reads as follows: "The section shows chronic osteitis but no tumor. The tissue

is composed of many irregular trabeculae of well formed bone, lying in loose new connective tissue. New bone formation is not active."

The mixed toxins were resumed after the amputation, and kept up for a considerable period. The patient was examined by one of us eight and one-half years later, at which time she was in excellent condition.

**CASE 18.**—*Periosteal osteogenic sarcoma of femur; amputation at hip joint followed by prolonged toxin treatment; patient well ten years later.*

J. H. F., a man, aged 48, was referred to us by Dr. David Barrow of Lexington, Ky. At the age of 4, the patient fell, sustaining a fracture of the right femur at about the middle. At the age of 11, he again fractured the same femur; he made a good recovery with normal function. At the age of 21, he had a slight periostitis at the site of the old fracture; no operation was performed, and he



Fig. 33 (case 32 in text).—Femur after three months' toxin treatment; patient well five years later.

remained well until June, 1916, when he noticed enlargement at the site of the old fracture accompanied by considerable pain and increasing disability. In August, 1916, a local operation consisting in curettage was performed, followed by roentgen-ray treatment (eight exposures). Temporary improvement followed this treatment but the tumor later again began to increase in size.

Physical examination at the time of his admission to the Memorial Hospital, Oct. 16, 1916, showed about  $3\frac{1}{2}$  inches (8.8 cm.) below the trochanter of the right femur, a hard, firm tumor covering the outer and anterior aspects of the leg from Hunter's canal downward for about 6 inches (15.2 cm.), extending around the femur for a distance of three-fourths of the circumference. There was an old cicatrix  $8\frac{1}{2}$  inches (21.5 cm.) long, the central portion of which was occupied

by an area of ulceration. There was slight dermatitis over the tumor, probably due to the roentgen-ray treatment. The course of the cicatrix was markedly indurated. The right thigh was atrophied. The tumor was fusiform in outline, firmly fixed to the femur, and apparently originated from it.

A roentgenogram, Oct. 19, 1916, showed extensive localized destruction of the femur, not, according to Dr. Herendeen, characteristic of periosteal sarcoma. There was thickening and fibrosis at the hila of the lungs but no evidence of metastasis nor of parenchyma; there was evidence of tuberculosis in the left lung. The patient was immediately put on the mixed toxins of erysipelas and *Bacillus*

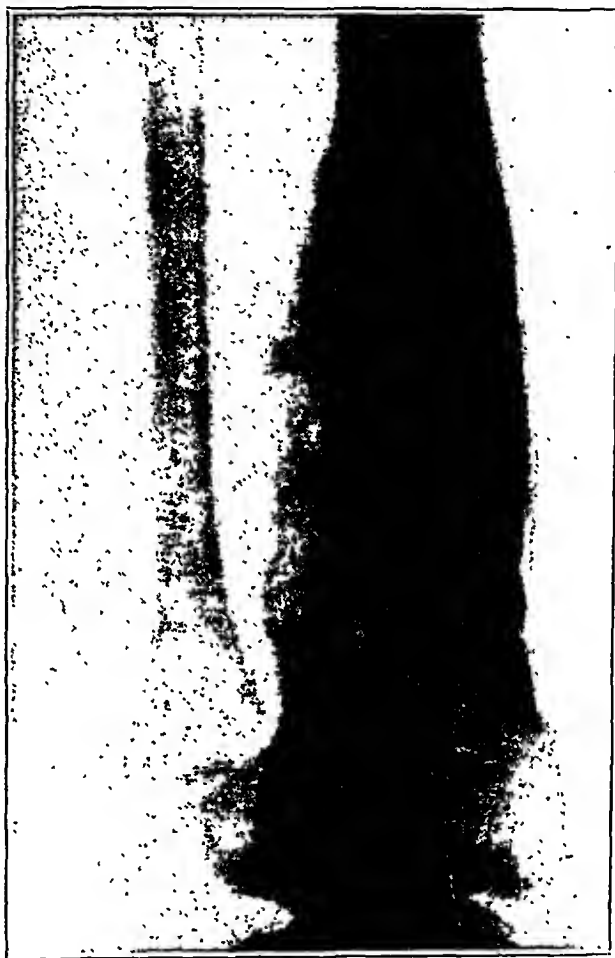


Fig. 34 (case 34 in text).—Clinical diagnosis: osteomyelitis; roentgen-ray diagnosis: endothelioma; no microscopic examination; recovery under toxins.

*prodigiosus*, supplemented by radium, 2,000 millicurie hours at 2 cm. distance. After two weeks' treatment, little improvement having taken place, a hip joint amputation was performed, October 31, by one of us. The toxins were resumed shortly after and continued by Dr. Barrow at home for a number of months. A microscopic report by Ewing read: "Large spindle and giant cell sarcoma. The structure resembles myosarcoma and not the usual bone sarcoma. The spindle cells are long, and the cytoplasm is very acidophil. The giant cells are mononuclear." A slide was later submitted to Dr. Francis Carter Wood, who pronounced it a spindle cell osteogenic sarcoma.

The patient is alive and well at the present time, nine years later. This case has been reported in the Bone Sarcoma Registry.

**CASE 19.**—*Periosteal sarcoma of femur (clinical and roentgen-ray diagnosis) involving upper half of femur; inoperable; treated by toxins and radium; well nine years; limb saved.*

R. H., a man, aged 36, with a negative family history, in January, 1917, fell on the ice, fracturing his left femur just below the trochanter. Roentgen-ray examination by Dr. George Hawley of Bridgeport, Conn., showed no evidence of a pathologic condition. Nine weeks later, a swelling developed at the site of the



Fig. 35 (case 34 in text).—Fourteen months later than figure 34.

injury and continued to increase in size. The patient remained in St. Vincent's Hospital in Bridgeport for twenty-seven weeks, after which he was referred to Dr. L. Fischer of the Lenox Hill Hospital, who in turn sent him to me.

Physical examination at the time of his admission to the Memorial Hospital, October 20, showed a huge tumor occupying the upper two thirds of the femur, apparently periosteal in origin, pathologic fracture and almost complete destruction of 5 inches (12.7 cm.) of the shaft; the circumference was 64 cm. The condition was considered entirely beyond hip joint amputation; 5 inches of the shaft had been destroyed. Roentgen-ray examination showed probable meta-stases of the lungs. From 1917 to June, 1918, he received local and systemic injections

of the mixed toxins; in addition, the radium pack (about 40,000 millicurie hours at 10 cm. distance) was applied in November, and again in December. The circumference of the leg diminished 8 cm.; there was some union of the pathologic fracture; roentgen-ray examination of the chest was negative. A Thomas splint was applied, and the patient returned home. He has remained in excellent condition, and was shown before the members of the Clinical Congress of Surgeons



Fig. 36 (case 35 in text).—Osteogenic sarcoma after four months' treatment with toxins and roentgen rays; patient gained 17 pounds (7.7 Kg.) in weight; circumference of thigh normal. The patient remained well for one and a half years, then developed a nodule in lung.

in October, 1925. Since January, 1919, he has been able to walk without a crutch or a cane; the only thing he has to wear is an orthopedic shoe, on account of the 5 inches shortening caused by the complete destruction of bone. He has been well for nine years.

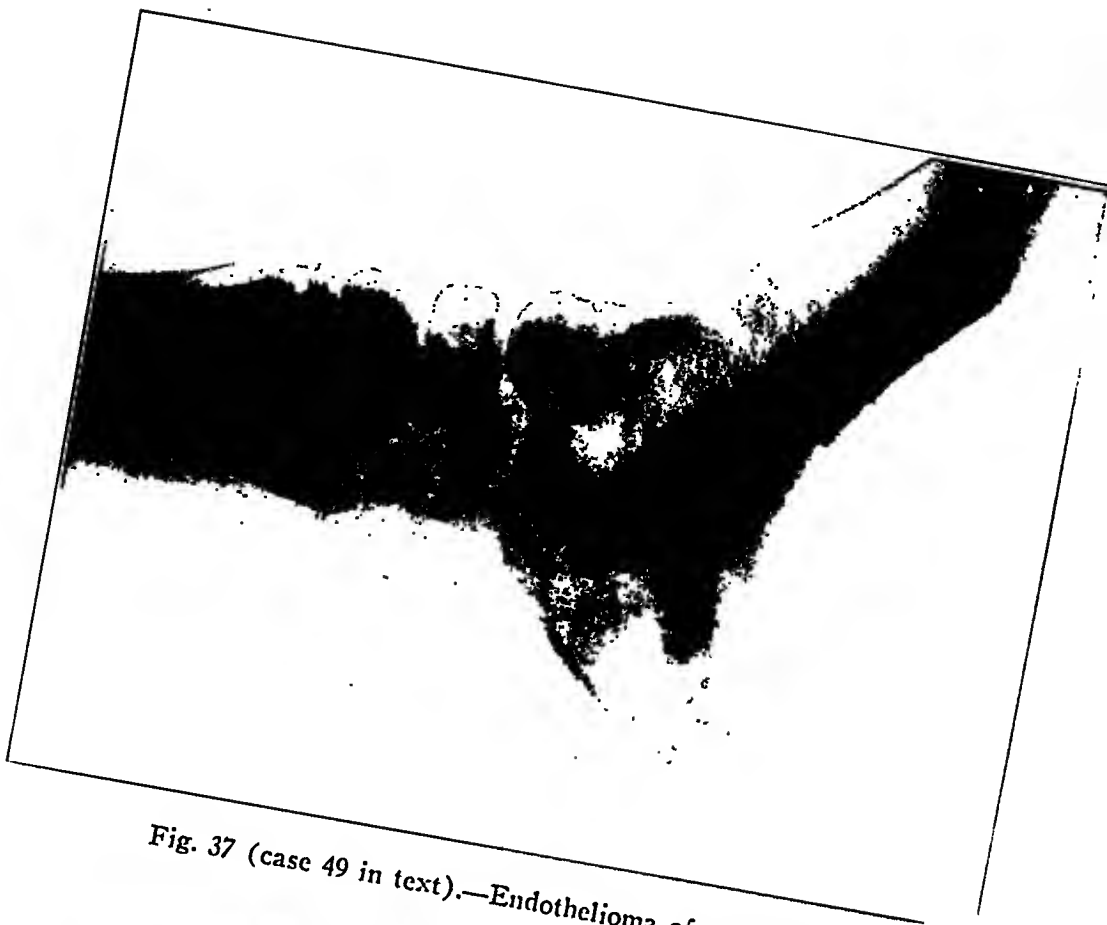


Fig. 37 (case 49 in text).—Endothelioma of os calcis.

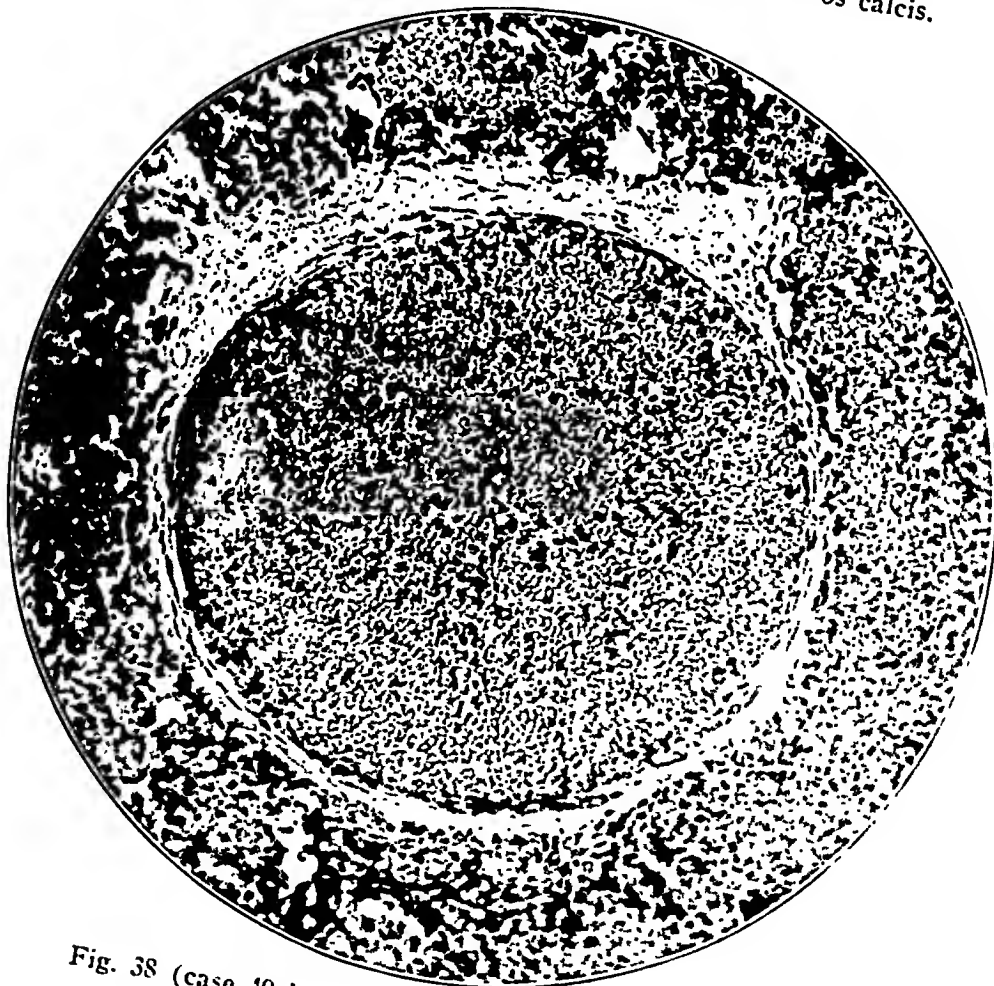


Fig. 38 (case 49 in text).—Endothelioma of os calcis.



CASE 20.—*Periosteal sarcoma of tibia.* R. W., a girl, aged 7 years, was referred to us by Dr. F. N. G. Starr of Toronto in June, 1917. There was no previous history of trauma. In December, 1916, the patient first noticed a swelling in the midshaft of the right tibia; this continued to increase in size. A number of roentgen-ray treatments were given in January, 1917, in Toronto, with temporary improvement. Roentgen-ray examination of the chest showed a number of apparent metastases of the lungs, although on this point one could not be absolutely certain.

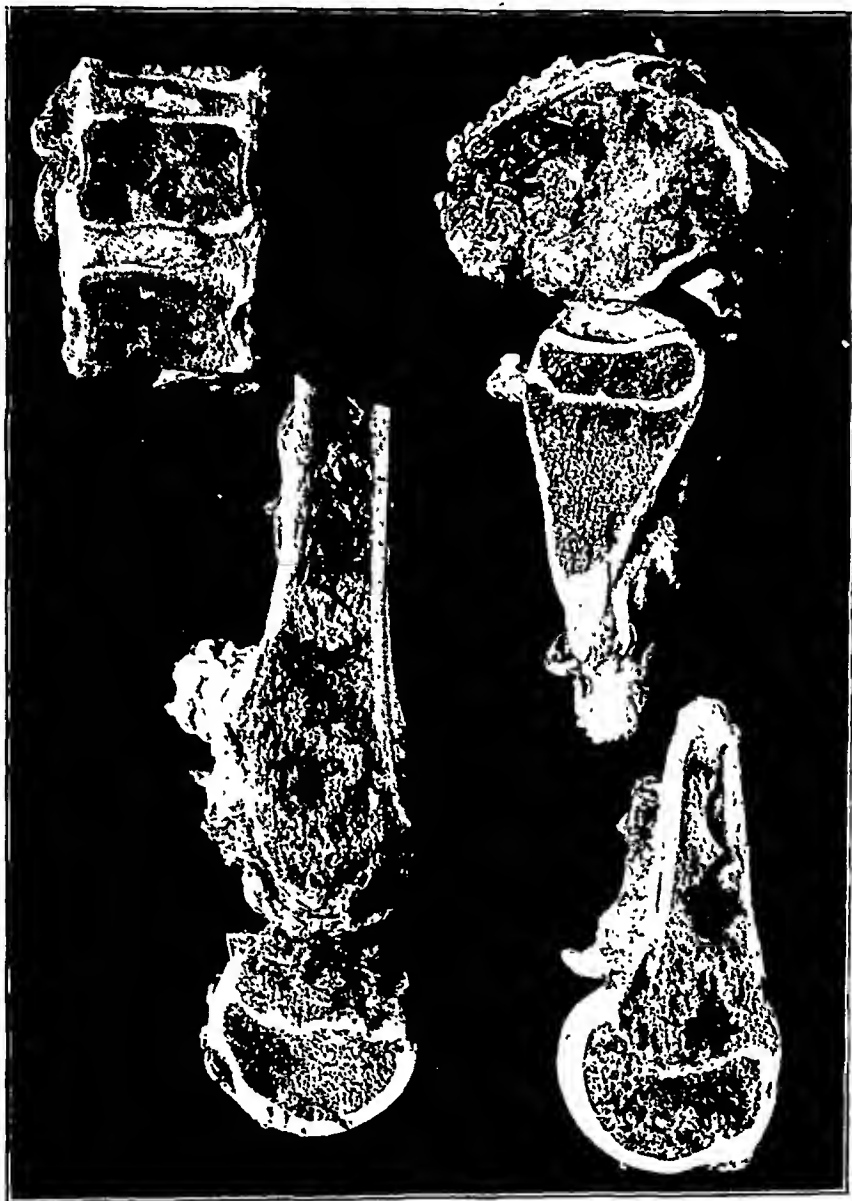


Fig. 39 (Ewing's case).—Specimens from patient 49 in text.

Roentgen-ray examination at the time of her admission to the Memorial Hospital, June 20, also showed probable lung metastases; therefore, three prophylactic roentgen-ray treatments over the chest were given while she was in the hospital. The toxins, which were started in June, were kept up until July 16, 1917, when in view of the fact that there was no marked improvement an amputation was performed at the middle lower third of the thigh. It is interesting to note

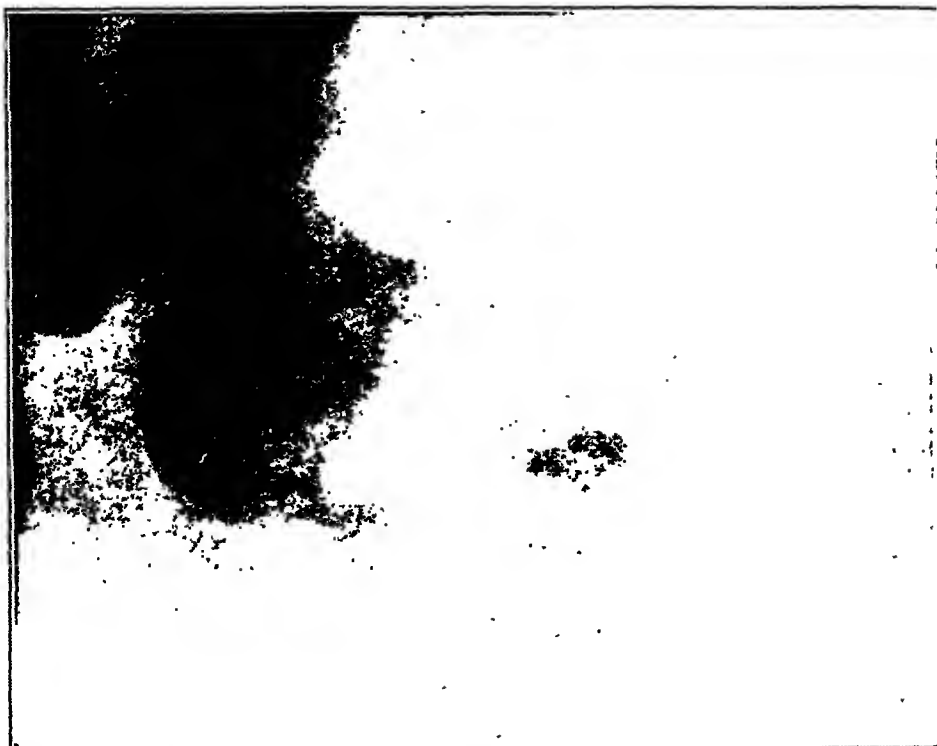


Fig. 40 (case 19 in table 7).—Endothelial myeloma of femur with metastases in spine.



Fig. 41 (case 42 in table 7).—Central malignant sarcoma of femur.

that the patient had an occasional temperature of 102 before the toxin treatment was given; this is one of the rare cases of sarcoma of the long bones associated with marked temperature. The tumor was apparently of periosteal origin with very extensive involvement of the greater portion of the shaft of the bone.

A microscopic examination was made by the pathologist of Toronto General Hospital, whose diagnosis was round cell periosteal sarcoma. The amputated leg specimen was examined by Ewing also, who reported diffuse endothelioma.



Fig. 42 (case 42 in table 7).—Two and one-half months later than figure 41. The patient developed metastases after amputation.

The toxin injections were resumed a few days after the amputation and continued for nearly six months after the patient left the hospital. She has remained in good health up to the present time, eight years later.

CASE 21.—*Periosteal sarcoma of femur with multiple metastases in skull.* W. L. B., a boy, aged 6 years, when about 3 years old, in 1916, fell from a pony;



fundus glands which are frequently hypertrophic (*état mameloné*). The fundus glands, however, are resistant to disease. Through the *pars oestorica*, or distal part, pass the active peristaltic waves which propel the food into the duodenum. It is lined by less differentiated mucosa which is not as resistant as the mucosa of the fundus glands and which is most frequently subject to the various forms of gastritis. It is also in this part of the stomach that ulcers and cancer are found.

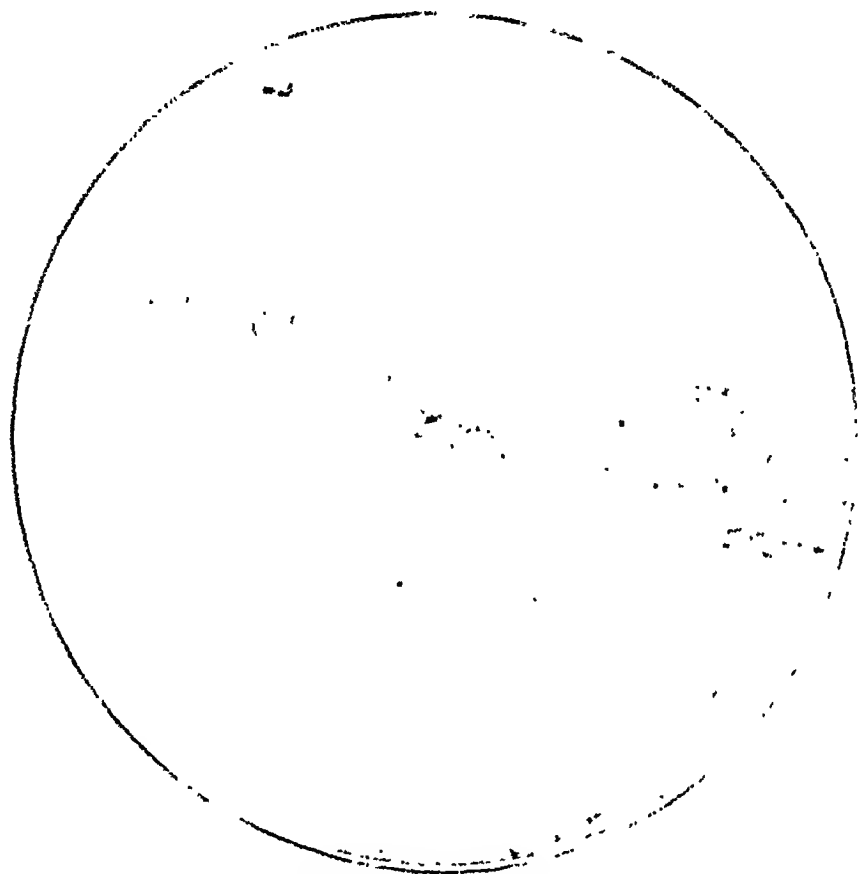


Fig. 21.—Low power magnification of a flat, large follicle uncovered by epithelium (follicular erosion).

#### SUMMARY

The histologic examination of twelve stomachs resected for ulcer of the duodenum or ulcer of the stomach and eight stomachs resected for cancer reveals that there are evidences of gastritis in the mucosa of all stomachs examined. This form of gastritis is characterized by islands of intestine-like mucosa, areas of dark-stained epithelium with evidences of regeneration and glands with numerous branching alveoli lined with a light-staining cuboidal epithelium (pseudopyloric glands of Stoerk), increase in size and number of lymph follicles and other lymphoid elements. Defects in the mucosa, erosions and small microscopic ulcers are frequently encountered.

On closer examination one finds that the cells possess a cuticular border. The cells with acidophilic granules are situated at the bottom of the tubules. The mucosa of the stomach epithelium stains red with the acid components of the Jenner stain, while the goblet cells stain blue with the basic elements of the stain.

There seems to be a dispute as to the true nature of these observations. The majority of investigators agree that such heterotopic intestine-like pictures are a result of the various destructive and pathologic processes of the stomach mucosa. Such islands are frequently sur-



Fig. 15.—Two islands of intestine-like mucosa found in otherwise normal pyloric mucosa. Low power magnification.

rounded by atypical glands. Hammerschlag,<sup>20</sup> Heyrovsky,<sup>3</sup> Stoerk<sup>4</sup> and Moszkowicz<sup>6</sup> believe that the aberrant islands in the mucous membrane are produced by pathologic processes. The adjacent epithelium covers the defect with an indefinite kind of epithelium which later gives rise to the stomach or intestinal type of epithelium.

Müller,<sup>25</sup> however, maintains that intestinal islands are due to disturbed embryologic development. He could not demonstrate any

25. Müller, P. F.: Beitrag zur Histologie und Parhogenese des Ulcus pepticum ausserhalb und innerhalb des Magens, Beitr. z. klin. Chir. 123:1, 1921.

The changes are mostly limited to the distal part of the stomach in the area of the distribution of the pyloric glands. The mucosa of the fundus displays a form of hyperplasia and hypertrophy with increase in the size and number of parietal cells described as *état mammelonné*. Contrary to the opinions and descriptions found in textbooks on pathology, *état mammelonné* is limited to the fundus mucosa and is not an inflammatory process.

The evidences of gastritis are more pronounced in specimens resected for cancer. Gastritis, ulcer and cancer are found most frequently in the area of distribution of the pyloric glands; the area of distribution of the fundus glands is seldom the seat of any disease of the stomach. The fundus glands are more differentiated and more resistant to any pathologic change than the pyloric glands.

The limitation of the varied diseases of the stomach to its distal part in the area of the distribution of the pyloric glands should be of interest and importance in relation to the surgical prophylaxis and surgical therapeutics of cancer and ulcer.







powers of the germ layer are more limited than those of the original ovum, and they become diminished with the gradual differentiation of the organ. Under normal conditions, the adult grown cell produces its own kind, while under experimental conditions, the dormant powers of the cell will have a wider scope.

The cells in the glands of the stomach mucosa are destroyed by various agents. The defects are healed by a rapid cell proliferation. Through the loss of connection with the surrounding old cells, new mechanical or chemical conditions are produced which have a tendency toward nondifferentiation. Under new conditions and new environment, the cells may demonstrate new possibilities through the awakening of dormant powers. In the crypts and tubules which have dark-stained epithelium the protoplasm and nuclei frequently have the appearance of a mass where the cell border may be absent and only nuclei are seen. In such groups of cells and nuclei there are groups of regenerated epithelium, goblet cells, Paneth cells and cells with cuticular borders.

#### EROSIONS

Microscopic ulcerations and defects in the mucosa were encountered in all the stomachs I examined. Some of these defects were funnel shaped (fig. 13) or resembled the structures of a chronic ulcer (fig. 16). Others had bizarre forms (fig. 17) and displaced only one or two tubules or only one foveola. Some extended to the muscularis mucosa, while others involved only the superficial part of the mucosa. Not a few of these ulcerations were in close relation to the many lymph follicles and the groups of round cells (figs. 18 and 3).

The adjacent epithelium at the edge of the defect either looks normal or is swollen, desquamated and mixed with leukocytes and lymphocytes. Even with low power magnification one frequently observes that the epithelium at the edge of the defect is stained darker than the rest. With high power magnification one sees that this epithelium shows definite evidence of regeneration and proliferation, not unlike the process seen in the healing of a chronic ulcer (figs. 17 and 16). The epithelium is seen to be fused in buds with numerous nuclei and a few polymorphonuclear leukocytes (fig. 14).

The funnel-shaped ulcerations are filled with mucous plugs or exudates containing leukocytes, lymphocytes and desquamated epithelium (figs. 18 and 13). At the base of an ulcer occasionally there is necrosis of tissue, and there is evidence of granulation tissue below. The defects are surrounded by glands, some of which appear normal, while others are branching, lined with an epithelium resembling that of the pyloric glands. The glands are directed either obliquely or perpendicularly toward the lumen of the defect. A rolling-in of the fan-shaped groups of glands toward the defect is also observed.

Recovery under expectant treatment.

Comment.

Summary.

The complications which result from fractures of the skull can be placed in three different categories, namely: (1) those that are inevitably fatal, (2) those for which the patient can be treated successfully by craniotomy and (3) those that heal spontaneously if treatment is not given.

In order to study the fatal cases, 512 cases which came to necropsy are here reviewed. Sixty-one clinical records are also presented so that the effects of craniotomy and the final results of expectant treatment may be considered.

## PART I. COMPLICATIONS CAUSING DEATH

### DESCRIPTION OF THE AUTHOR'S MATERIAL

The 512 necropsies referred to in this article were performed by me or were seen in my work as Assistant Medical Examiner of New York

TABLE 1.—*Age Incidence and Casualties in 507 Necropsies*

Age	No. of Cases	Age	No. of Cases
1-10.....	46	50-60.....	87
10-20.....	20	60-70.....	58
20-30.....	63	70-80.....	25
30-40.....	90	80-90.....	2
40-50.....	115	90-100.....	1
Casualty Incidence			
Automobile accidents.....	189	Knocked down in assault....	11
Street car accidents.....	19	Horse kick.....	1
Bicycle accident.....	1	Struck by blunt instrument.	21
High falls.....	41	Hit by falling object.....	5
Low falls.....	61	Hit by flying object.....	1
Fall down stairs.....	51	Hit by moving object.....	3
Thrown down in assault....	3	Nature of casualty unknown	100

City between Jan. 1, 1920, and March 15, 1926. Five cases of the entire number were those of infants under 5 years of age, and these are considered separately. The remaining 507 cases included persons of all ages and conditions. Of this number, 445 were men and sixty-two women, which is the proportion to be expected in cases of injury. Taken by decades, the age incidence showed that the middle period of life is the one in which fracture is most likely to be included. The figures for the different ages are given in table 1. Highway accidents, which included automobile, street car and bicycle accidents, formed over 40 per cent of all the cases. The fracture was generally produced by the vehicle striking the person's head directly, by knocking his skull against the street or by crushing his head in some way.

The other types of injury were caused by the head striking against a solid surface, or were produced by some object coming into violent contact with the head. The first group included falls or assaults in which



Fig. 16.—Microscopic ulcer from the antrum showing all the histologic characteristics of an old chronic ulcer.



Fig. 17.—Circular ulcer demonstrating attempts at healing by fibrous tissue.

the deceased was either knocked or thrown down. The second group comprised assaults by blunt instruments, kicks by horses, blows and falling objects of any kind striking the head.

In 100 cases the cause of the fracture was unknown, as the deceased was found either dead or in a coma. Most of these injuries were probably caused by falls.

#### CLASSIFICATION OF THE FRACTURES OF THE SKULL

It is necessary to classify fractures of the skull according to their location, form and extent, because these features generally suggest the intracranial complications that are likely to be present. Any attempt of this kind, however, is difficult, as the fractures cannot be separated easily into definite, well marked categories. Many transitional forms occur which are hard to fit into any scheme of classification.

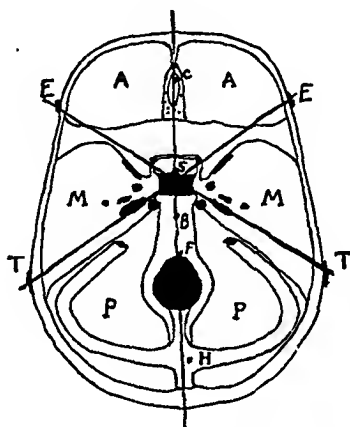


Fig. 1.—Diagram of the base of the skull showing its separation into fossae and how the boundaries of the fossae converge toward the body of the sphenoid bone. *A* represents the anterior fossa; *M*, middle fossa; *P*, posterior fossa; *E*, location of the external angular process of the frontal bone; *T*, location of the mastoid process of the temporal bone; *C*, crista galli of the ethmoid bone; *S*, body of the sphenoid bone; *B*, basilar process of the occipital bone; *F*, foramen magnum; *H*, torcular Herophili.

A preliminary consideration of the anatomic characteristics of the skull and the way in which different fractures are produced, however, is helpful in attacking the problem.

First, the skull must be regarded as an oblong box composed of a vault and base. The vault is a strong, curved dome of bone, of even thickness, with the exception of two fragile plates in each temporal region. The base, however, is an irregularly flattened structure, composed of heavy masses of bone, weakened by thin plates, numerous foramina and bony cavities. The strong and weak points in the base, furthermore, have a systematic arrangement which is best illustrated by a diagram (fig. 1).

when the abdominal muscles and the diaphragm are responsible for the compression of the viscera. The recoil waves of the blood in the portal circulation are stopped when the blood in the capillaries of the portal system meet the arterial capillaries close under the mucous membrane. The capillaries burst, and a hemorrhage is produced. Beneke,<sup>29</sup> however, is of the opinion that such primary hemorrhages are not of importance in the formation of hemorrhagic erosions as generally understood.

The embolic theory has been emphasized by many European and American authors from the pathologic observations and experimental work. Vasomotor changes of the arterioles have been considered responsible for such hemorrhages. Hemorrhages and erosions have also been produced experimentally through the spasm of the muscularis mucosa by the injection of pilocarpine. There are many other experimental methods by which hemorrhagic erosions can be produced.

The etiologic factors of the erosions found post mortem, or produced experimentally, are closely related to the agonal phenomenon of death. Just before death, when the muscle of the heart becomes weak, and its action such that the circulation in the stomach mucosa is slower and weaker, a rapid focal digestion may take place, causing erosions. The various toxins of infectious diseases causing parenchymatous changes in the other organs of the body may, in the same manner, easily disturb the protective agency of the stomach mucosa against self-digestion, and also produce various hemorrhagic erosions.

The erosions and defects described are found in the mucosa, which is subject to gastritis in its various manifestations. I could not find any changes in the blood vessels or hemorrhages in the mucosa which would explain the etiology of these defects. Nauwerck<sup>30</sup> and Konjeczny<sup>5</sup> have also failed to find any changes in the blood vessels, such as endarteritis, sclerosis, emboli or thrombosis, which would explain the acute formation of these erosions. The histologic picture of the defects found in the surgical material concomitant with the pathologic condition of the rest of the stomach mucosa makes these defects and erosions different from the hemorrhagic erosions found post mortem.

#### THE NATURE OF INFLAMMATION

The nature and significance of the histologic picture and the factors concerned in the production of such frequent changes in the mucous membrane of the stomach are still problematic. The gastritis is evidently

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29. Beneke, R., quoted by Aschoff, L., *Pathologische Anatomie*, ed. 6, Jena, Gustav Fischer, 1923, vol. 2, p. 715.

30. Von Nauwerck, C., quoted by Konjeczny, George Ernest: *Chronische Gastritis und Duodenitis als Ursache des Magenduodenalgeschwürs*, *Beitr. z. path. Anat.* 71:595, 1923.

The base shows a division into six fossae, two anterior, two middle and two posterior. A strong mass of bone, the external angular process of the frontal, separates the outer extremity of each middle fossa from the anterior fossa in front. In the same way, the mastoid and petrous processes of the temporal bone separate the middle and posterior fossae. Strong structures of bone also come between the two anterior and the two posterior fossae. As figure 1 indicates, the body of the sphenoid is the common center or hub which connects these masses by long ridges, forming a radiating figure with six spokes.

The bone between the spokes forms the floor of the different fossae, and is generally thin, especially over the orbital roof and middle ear cavity. The spokes are, however, rather strong and tough, except at the different points of weakness in the anterior and posterior boundaries of the middle fossae, of which the sphenoidal fissures and the ear cavities are the most important. The central point of the skull is also rendered less resistant by numerous foramina and cavities. The alternating areas of strength and fragility have an important influence on the course of the fracture lines in the skull.

The fractures are almost always produced by the application of violence to the vault, which causes the skull to change its shape, so that the bone becomes especially flattened at the site of impact. The fracture lines generally start at this point, as it is here that the greatest strain is thrown on the continuity of the cranial bones.

The fractures follow certain well defined rules. In most instances they run from the vault down into the base, though sometimes they travel along the vault instead. In the base, the fracture lines generally select the bed of the fossae between the strong masses of bone that form its boundaries and, for the most part, are directed toward the central point of the skull. The fractures also tend to run in the direction of the line of violence. When the point of impact is in the back of the head, the direction is from the back to the front. When the force strikes on the side of the head, the fracture runs toward the opposite side, and if the contact is in the frontal region, the fracture is directed posteriorly.

In general, the crack in the bone has a tendency to seek the lines of least resistance. An expanse of skull with gradual curvature is less resistant to violence than an area of bone with sharp curvature, and the fracture most often seeks out the former unless other factors are present which modify its course. The normal suture lines of the skull, especially on the vault, are also involved in many fractures because they are naturally weaker than the rest of the bone.

The most convenient classification of fractures is into the two main categories of: (1) those involving both vault and base, among which are included a few confined to the base alone, (2) those involving only the vault.

not a result of actual invasion of bacteria, since there is seldom a typical picture of bacterial inflammation or the type of inflammation that is usually seen in the mucous membrane of other organs. This form of gastritis is characterized by a proliferative and regenerative phenomenon resulting in the pseudopyloric glands of Stoerk, the intestinal islands and the dark-stained groups of epithelium, formation of microscopic ulcerations and increase in the lymphoid elements.

Usually the repair of injuries is characterized by the formation of intensive blood supply, granulation tissue and the elimination or absorption of the injurious substances, and later by an attempt at restoration to normal. Marchand<sup>21</sup> points out that an attempt of the organ to repair loss of tissue and to regenerate is not always accompanied by inflammation. The process of inflammation is developed only in the higher vertebrates, and even among these there are definite differences. In the lower animals the defense against injury is accomplished only through the process of regeneration. The same process takes place in the early stages of the human embryo, and only in its later stages does inflammation occur.

In the stomach mucosa an infiltration of leukocytes and an increase in the number and size of the lymph follicles are observed; however, as Moszkowicz has pointed out, these changes are not always related to the erosions and ulcerating areas or the islands of heterotopic epithelium, and even in chronic callous ulcers there are only a small wall of leukocytes and edema. The reaction of defense does not appear to be commensurate or significant in comparison with the reaction of the same insults to the mucous membrane of other organs. Moszkowicz believes that gastric juice is directly responsible for the inhibitory influence on the inflammatory process. The formation of granulation and scar tissue takes place when the muscularis mucosa is broken through, but even here the gastric juice prevents any extensive formation of the components of inflammation. Only when the liver, pancreas or other organs in the abdomen are near an ulcer does an inflammatory peritonitis prevent a sudden perforation of the ulcer. When the ulcer faces the free abdominal cavity, there is often a perforation without previous symptoms because there has not been sufficient inflammatory reaction.

It is possible that the factors which cause the changes in the stomach mucosa are of a protean nature. Acute gastritis produced in the course of an infectious disease through the action of bacterial toxins, or through a direct bacterial invasion of the wall of the stomach, may be the beginning of chronic gastritis. In the discussion on the erosions I have men-

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<sup>21</sup> Marchand, F.: Der Prozess der Wundheilung mit Einschluss der Transplantation, *Deutsche Chirurgie*, Stuttgart: Ferdinand F. A. G., 1904.



The first category was further subdivided according to the distribution of the fractures into: (a) posterior fractures; (b) lateral fractures, and (c) anterior fractures.

A further subdivision was made, according to the form and extent of the fracture, into: (a) linear or fissure fractures, single linear cracks in the bone, showing at the most only a few minor side branches; (b) composite fractures or fractures composed of several fissures. The milder forms showed only a few fracture lines running in the same direction as the line of violence. Others showed extensive comminution of the bone at the site of injury.

The vault fractures were subdivided into: (a) linear fractures; (b) composite fractures, and (c) depressed fractures. The last named category was identified whenever the bone was broken into several plates and depressed inward in a limited, sharply defined area of the vault. The arrangement of the material in this classification is shown in table 2.

TABLE 2.—*Kinds of Fractures Studied*

Fractures involving vault and base.....	471
(1) Posterior location .....	178
(a) Linear fractures .....	96
(b) Composite fractures .....	82
(2) Lateral location .....	232
(a) Linear fractures .....	99
(b) Composite fractures .....	133
(3) Anterior location .....	61
(a) Linear fractures .....	26
(b) Composite fractures .....	35
Vault fractures .....	36
(a) Linear fractures .....	12
(b) Composite fractures .....	16
(c) Depressed fractures .....	8

*Fractures Involving Vault and Base.*—(1) Posterior Location: The posterior fractures were relatively numerous; they occurred in about 35 per cent of the entire number of cases. They all followed an impact in the posterior region of the vault which caused shortening of the sagittal diameter of the skull. The lines of fracture traveled down into the posterior fossae in the majority of instances, although some also extended into other regions of the skull (figs. 2 and 3).

(2) Lateral Location: As the sides of the vault are the most expansive areas in the cranium, and as the bone is the flattest and most exposed to the trauma, it is not surprising that lateral fractures reached the proportion of 45.9 per cent. They were invariably caused by an impact against the side of the head which produced shortening of the lateral axis of the skull. The fracture ran forward and downward in the majority of cases, running transversely through the floor of the middle fossa toward the sella turcica or the sphenoidal fissure. They often extended beyond the boundaries of the fossa to the anterior fossae or the middle fossa on the opposite side (figs. 4 and 5).

tioned the pepsin-antipepsin balance, which is easily disturbed and which contributes to the various acute lesions of the stomach mucosa. Repeated chemical, thermal and mechanical injuries to the mucous membrane through indiscretions of diet, causing the various disorders of the stomach in infants and transitory dyspepsias in adults, are considered to be a starting point in the production of the histologic chronic gastritis. The mechanical, thermal and chemical insults may not be extensive, but if repeated will eventually terminate in a chronic gastritis. According to Stoerk,<sup>4</sup> chronic gastritis can be produced only by various insults of the stomach mucosa through the innervation peculiar to the stomach, since the repeated injuries are not extensive.

When the wall of the stomach of an experimental animal is stimulated in one part, even if the omentum is pinched by an artery forceps, the whole wall becomes pale. Occasionally a depression can be seen in the wall of the stomach after the omentum is pinched. Stoerk believes that it is this peculiar innervation through which an injury in one part of the stomach, bringing other parts of the stomach into reflex and sympathetic stimulation, may disturb the secretory innervation and injure the pepsin-antipepsin balance. Limited and repeated injuries to the stomach mucosa can produce an extensive gastritis through a process of multiplication of the injury connected with its peculiar innervation.

#### COMMENT

The pathologic changes observed in the mucosa of the antrum reach higher along the lesser curvatures of the stomach. Some of the valleys are covered by only one layer of epithelium, which is frequently desquamated or destroyed. The fan-shaped groups of glands bend over so as to cover some of the walls almost completely. It is possible for the gastric juice to be held in these depressions for a longer period than usual, which leads to desquamation or ulceration of the mucosa.

The various microscopic erosions and defects found in all stages of destruction and healing do not resemble the typical fresh hemorrhagic erosions, the so-called stigmas of Beneke and the experimentally produced erosions. In this connection a more critical interpretation must be made of the experimental work as related to focal infection as the etiologic factor of ulcer of the stomach or duodenum. I have pointed out the vulnerability of the stomach mucosa, the agonal factors of death contributing to the formation of hemorrhagic erosions and the numerous agents which have been employed in experimental work and which have been successful in producing stomach erosions.

I was impressed with the ulcerations and defects found in the stomach mucosa of the surgical material examined as closely related to the concomitant gastritis found in these stomachs. I was not able to

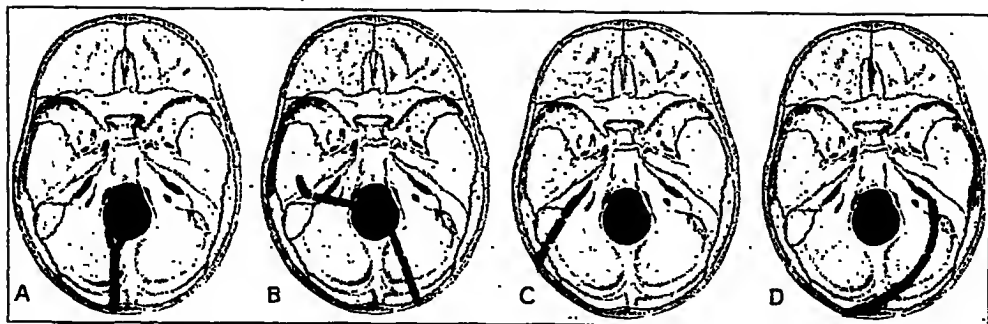


Fig. 2.—Types of posterior linear fractures. *A* represents linear fracture running into the foramen magnum; *B*, linear fracture crossing the foramen magnum and invading the petrous portion of the temporal bone on the opposite side; *C*, linear fracture running into the jugular foramen; *D*, linear fracture crossing posterior fossa to end in the jugular foramen on the opposite side.

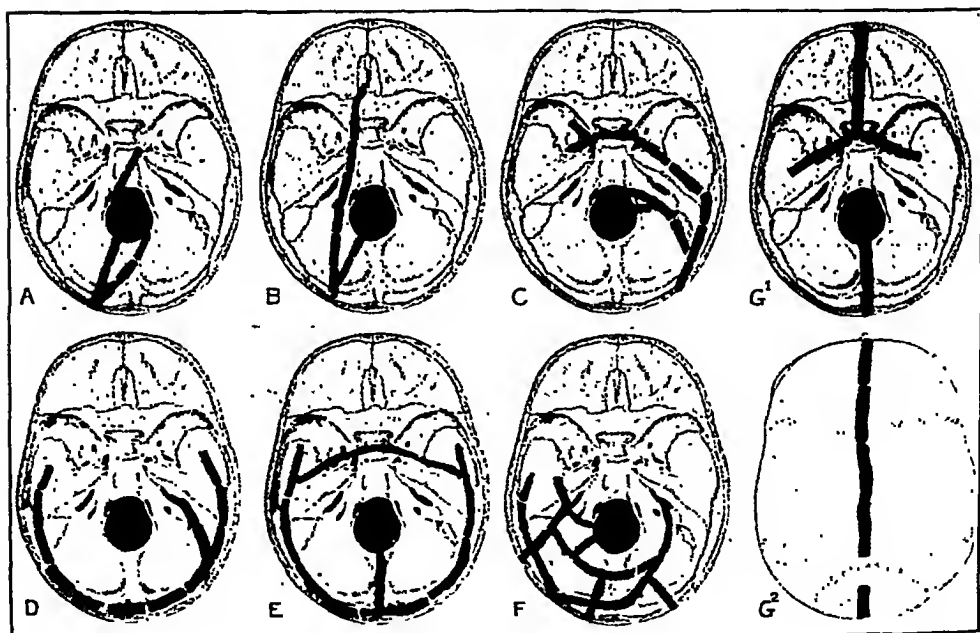


Fig. 3.—Types of posterior composite fractures. *A* represents angular type of posterior composite fracture; *B*, angular type of posterior composite fracture; *C*, dendritic type of posterior composite fracture; *D*, dendritic type of posterior composite fracture; *E*, extensive posterior composite fracture where the fracture lines joint at the sella turcica and isolate the posterior portion of the base from the rest of the skull; *F*, comminuted type of posterior composite fracture; *G*<sup>1</sup> and *G*<sup>2</sup>, base and vault distribution of a posterior composite fracture which practically bisects the skull in the sagittal plane.

find any emboli or thrombi or any further evidence of disease in the smaller blood vessels near the ulcerations. It is still a debatable point which is primary, gastritis or the erosions and ulcer. Nanwerck<sup>32</sup> and Konjetzny<sup>33</sup> are of the opinion that ulcer is secondary to gastritis. Hauser,<sup>34</sup> Hemeter,<sup>35</sup> and Heydorsky<sup>36</sup> have indicated that gastritis is secondary to ulcer. Konjetzny, on examination of several hundred specimens, has repeatedly called attention to the small erosions of the stomach which are found concomitant with ulcer of the stomach and duodenum and which are in the various stages of healing. He believes that the erosions change into chronic ulcers under the influence of functional and chemical factors.

Many investigators now agree that a chronic ulcer originates in a small erosion. Most of the erosions heal, with the exception of those found on the lesser curvature at the pylorus or at the isthmus of the stomach, which become chronic ulcers. Archoff<sup>37</sup> has called attention to the anatomic and physiologic factors as related to the production and chronicity of the ulcers along the lesser curvature. He believes that the sperm of the narrow pass and the highway of the stomach are the anatomic and physiologic contributing factors. He also points out the deficient blood supply of the lesser curvature.

I have frequently observed in the specimens examined that when cancer does not originate in a chronic ulcer, it is closely associated with a peculiar heterotopic and hypertrophic condition of the glands of the stomach. The glands have lost their resemblance to the original fundus or pyloric glands. The tubules and alveoli are increased in size and number. The glands are heterotopic and irregular, with a few microcysts present. The cells lining the tubules are large, definitely high columnar, light staining with basal nuclei (fig. 19). It is difficult to state whether such disease pictures represent a hypertrophic form of gastritis or definite cancer. It is my opinion that such a hypertrophic mucosa represents a precancerous condition, since I find concomitant with such pictures definite cancer, tubular or of a simple infiltrating type (fig. 20). I hope to consider this phase of pathologic conditions of the stomach in another article.

I wish to emphasize the division of the stomach into two parts, a fact which is of etiologic interest and worthy of consideration from a therapeutic point of view. The pars digestoria, which is the largest proximal part of the stomach, makes only tonic contractions, and is lined by

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32. Hauser, Gustav: *Des chronische Magengeschwür*, Leipzig, F. C. W. Vogel, 1883.

33. Hemeter, John C.: *Experimental Basis of the Dietetic and Medicinal Treatment of Hyperacidity and Gastritis*, J. A. M. A. 29:196 (Oct. 9) 1897.

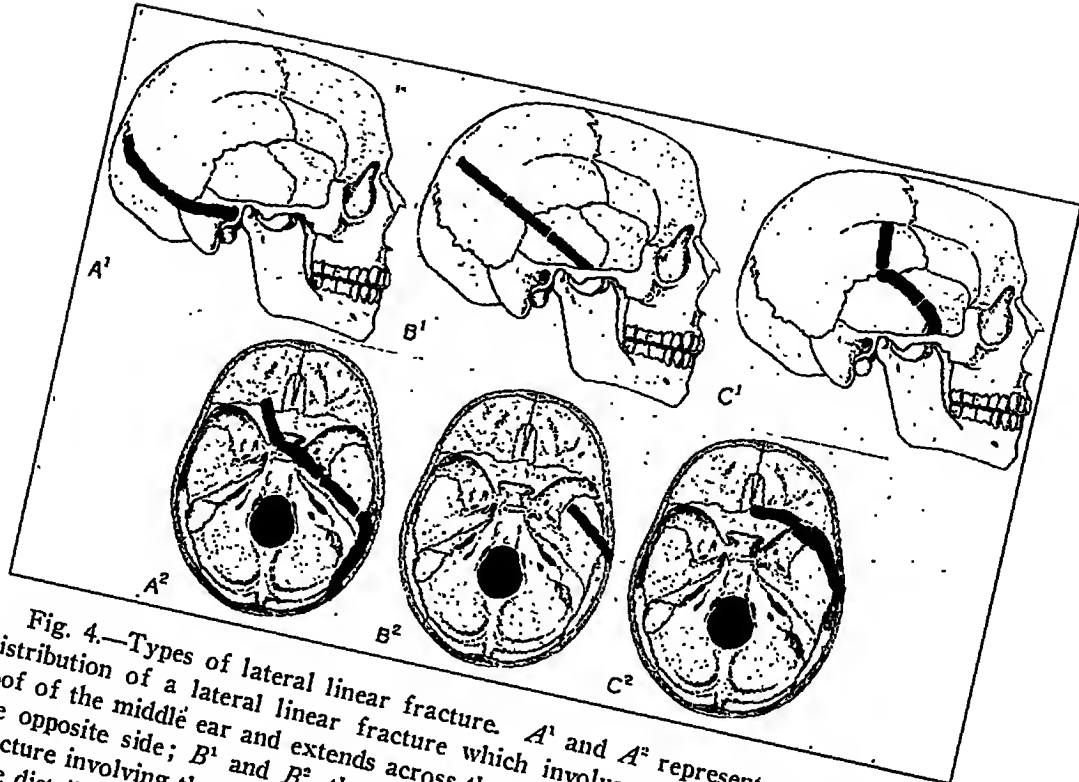


Fig. 4.—Types of lateral linear fracture.  $A^1$  and  $A^2$  represent vault and base distribution of a lateral linear fracture which involves the lambdoid suture, the roof of the middle ear and extends across the sella turcica to the anterior fossa of the opposite side;  $B^1$  and  $B^2$ , the vault and base distribution of a lateral linear fracture involving the parietal bone and the middle fossa;  $C^1$  and  $C^2$ , the vault and base distribution of a lateral linear fracture which involves the temporo-sphenoidal suture line, crosses the sphenoidal fissure and ends in the anterior fossa of the same side.

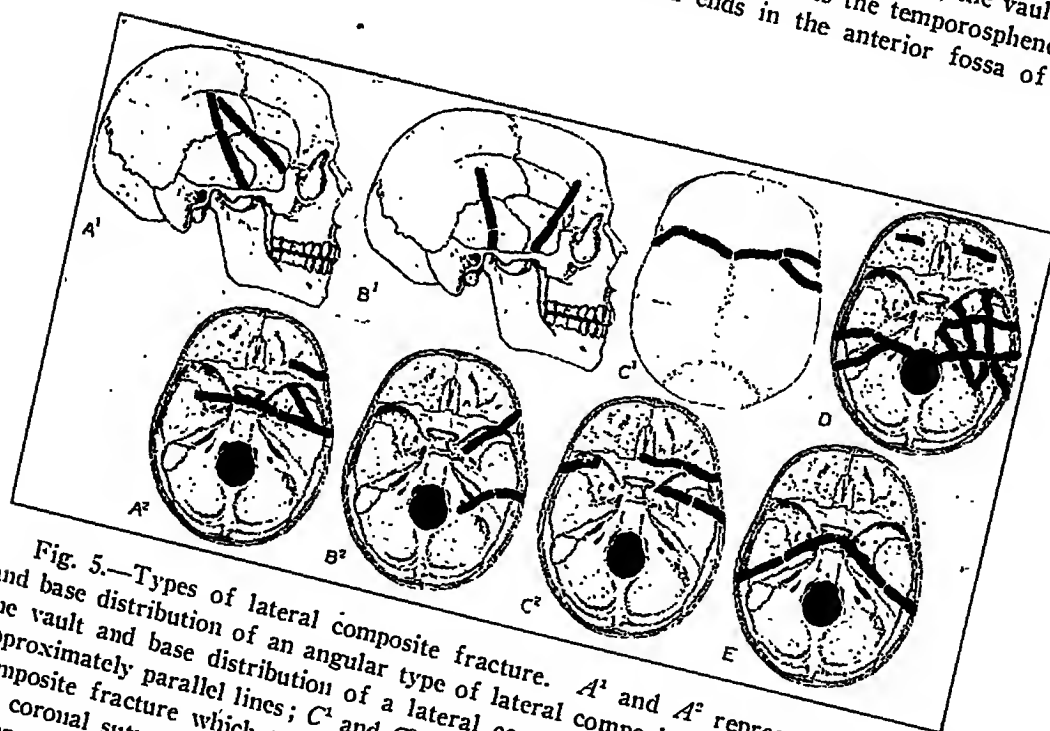


Fig. 5.—Types of lateral composite fracture.  $A^1$  and  $A^2$  represent the vault and base distribution of an angular type of lateral composite fracture;  $B^1$  and  $B^2$ , the vault and base distribution of a lateral composite fracture composed of two approximately parallel lines;  $C^1$  and  $C^2$ , the vault and base distribution of a lateral composite fracture which tends to divide the skull transversely in the region of the coronal suture;  $D$ , comminuted type of lateral composite fracture;  $E$ , lateral composite fracture caused by the crushing force of an automobile wheel which bisects the base of the skull.



Fig. 19.—From the same specimen as figure 20, showing the proliferating mucosa at the ulcerated edge of the cancer. (It is not possible to state definitely whether this is a proliferating type of gastritis or actual cancer.)

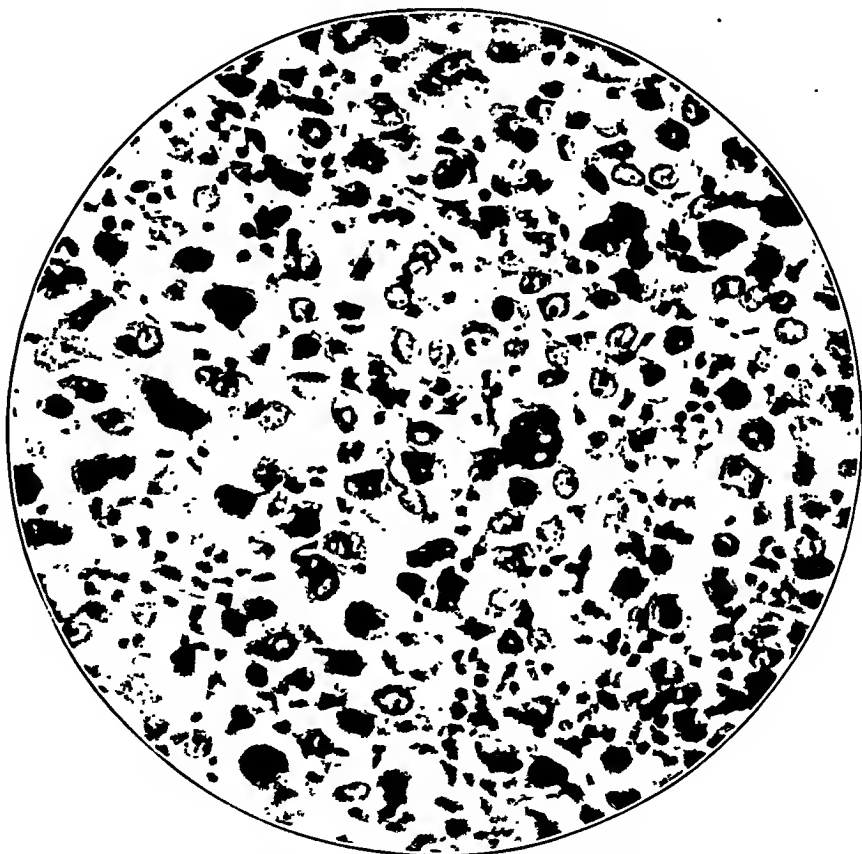


Fig. 20.—Infiltrating simple type of cancer.

Some peculiar types of lateral fracture were produced by a crushing force and not by a sudden impact. The causative agent was invariably an automobile. The wheel passed over the head, compressing the skull laterally and, as a rule, the base splint across the middle fossae, though other areas were involved as well. The fissures usually gaped open rather widely, and the base of the skull could be readily separated across the line of fracture (fig. 5 *E*).

(3) Anterior Location: The anterior region is a fragile structure of bone, easy to fracture, but apparently not subject to so much trauma as the other portions of the skull. Consequently, the fractures in the anterior region were comparatively few, only 12.5 per cent of the total

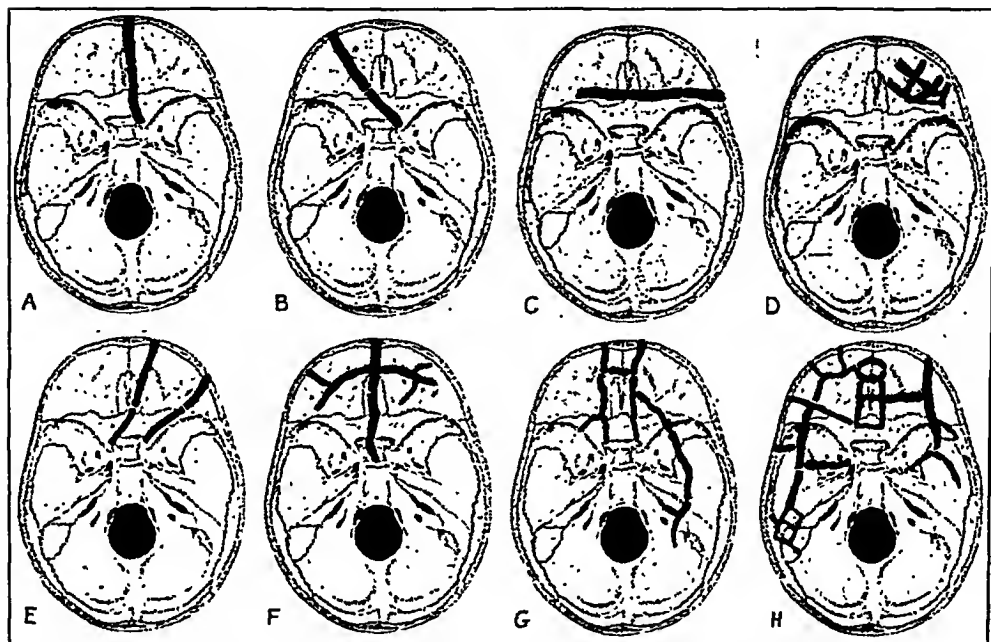


Fig. 6.—Types of anterior fracture. *A*, *B* and *C* are anterior linear fractures; *D*, small comminuted fracture of the anterior fossa; *E*, anterior composite fracture composed of two approximately parallel lines; *F*, anterior composite fracture; *G*, anterior composite fracture; *H*, extensively comminuted type of anterior composite fracture.

number. Most anterior fractures were the result of violence applied to the front part of the head, which resulted in a shortening of the sagittal diameter of the skull. The lines of fracture traveled backward toward the optic foramina and sometimes extended into other portions of the base. Occasionally the impact occurred in the lateral part of the frontal region, in which event a transverse fissure across both anterior fossae was produced (fig. 6).

The orbital plates were sometimes broken when some other part of the skull was struck. Any connection between the fracture arising near the point of impact and the orbital lesion often was not obvious. The

a tumor developed in the upper third of the shaft of the femur. This grew rapidly, and in August, 1917, an amputation was performed by Dr. Stuart McGuire of Richmond, Va. The microscopic diagnosis was periosteal sarcoma of the round cell type with no giant cells.

In October, 1918, he first noticed a swelling in the right parietal bone, and beginning exophthalmos; there was a softened area of the skull, which steadily increased in size. At the time of my first observation in June, 1919, there was a depressed area occupying nearly the whole right parietal region and apparent absence of bone over the area, 2 by 3 inches (5 by 7.6 cm.) in size; pulsation was easily felt; there was marked exophthalmos. Roentgen-ray examination by



Fig. 43.—Central malignant osteogenic sarcoma of tibia; exploratory operation followed by prolonged toxins; limb saved; patient well four years later.

Dr. Quick showed destruction of both tables of the skull over the midparietal region, and an extensive intracranial tumefaction beneath which strongly suggested a cyst. A hopeless prognosis was given, but a trial with the mixed toxins was advised as a palliative measure. The toxins were begun June 6, 1919, in doses ranging from one-fourth to 3 minims; thirteen injections in all were given at this period; marked reactions were obtained. The injections were then continued at home. In addition, the patient received two radium pack (lead tray) treatments over the right temporal and frontal regions (total of 12,847 millicurie hours) at 3 cm. distance. He was readmitted to the Memorial Hospital, Aug. 6, 1919, at which time the exophthalmos was found to have nearly disappeared, and the



tumor mass in the brain was barely palpable. Two radium pack (lead tray) treatments were given over two areas of the right temporal region (total of 5,867.2 millicurie hours) at 30 mm. distance. October 2, another radium pack was applied over the right temporal region (2,940 millicurie hours). March 2, 1920, the lead tray was applied over two areas, the right parietal and the supraorbital regions (2,992 millicurie hours each). Roentgen-ray examination



Fig. 44 (case 67 in table 7).—Central malignant sarcoma of tibia simulating giant cell sarcoma.

at this time failed to reveal any palpable tumor; the bulging of the eye was slight. The patient's general condition was excellent. In the latter part of April, 1920, he developed a similar tumor with marked bone destruction in the occipital region, 1 by 2 inches (2.5 by 5 cm.) in diameter and easily shown by the roentgen rays. According to Dr. Herendeen, the roentgenograms of the skull revealed evidence indicating further bone formation in areas previously involved in the

name of "contre coup fracture" has been given to such orbital cracks, but the term is meaningless. The orbital roof merely broke because it was especially vulnerable to strain and was unable to withstand the change of shape induced by the violence.

*Fractures of the Vault.*—Fractures of the vault were comparatively uncommon, forming only 6.7 per cent of the total number. Usually only those lesions were included in which the lines of fracture were confined mostly to the vault. Exceptions were made, however, in two cases in which the skull was extensively comminuted, both vault and base, due to an extreme grade of violence applied to the top of the head. Such injuries seemed to fit into the classification more logically here than elsewhere (fig. 7).

Of the different varieties, linear fractures were found in the parietal region. They were all short, and most of them ran downward and forward. One, however, ran downward and backward. They were, in all probability, produced by impact against the lateral part of the skull.

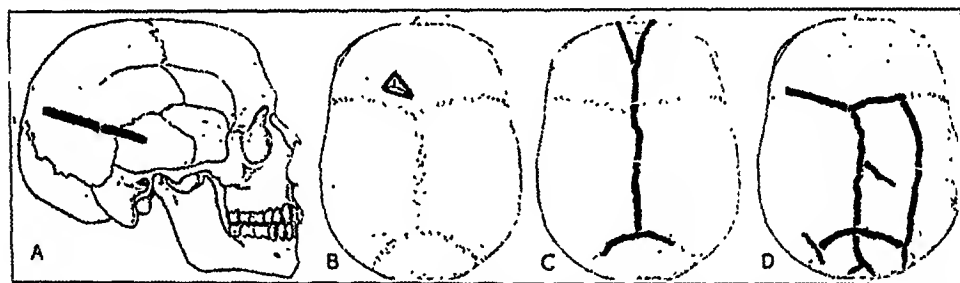


Fig. 7.—Types of vault fracture. *A* is a linear fracture of the vault; *B*, a depressed fracture of the vault; *C*, a composite fracture of the vault; *D*, a composite fracture of the vault.

Composite fractures generally were found on the vertex of the vault. Most of them were extensively comminuted, but a small number showed only a few branching lines.

Depressed fractures were a special type confined to the vault. They were caused by an object with a limited area of impact coming in contact with the skull; in most instances, this was a blunt instrument wielded with homicidal intent. A few were probably caused by falls against a projection. The appearance of the depressed fracture depended on the size and shape of the blunt instrument. The edge of a flatiron produced a triangular depressed fracture. A blackjack caused a roughly ovoid depression. In fact, the character of the depressed fracture not infrequently gave an important clue to the type of blunt instrument that was used (fig. 8).

In this connection, it is important to note that many fractures caused by blunt instruments were not classified as depressed fractures of the vault. The instrument was often large and the blow violent, so that the



Fig. 10.—Direct laceration of the outer surface of the right cerebral hemisphere caused by a lateral composite fracture of the right parietal and temporal regions. The depth of the laceration is shown in the section of the brain.

fracture lines sometimes extended to other regions. It seemed more fitting to enter these lesions elsewhere in the classification.

Two freak examples of fracture occurred which were included, for the sake of convenience, among the composite fractures of the vault and base. The force which produced them, however, was unusual. The persons in question fell, striking on the vertex of the head, and both sustained fractures of the base, around and just anterior to the foramen magnum. There was evidence that the weight of the body, transmitted through the spinal column, forced the articular process of the occiput up through the base of the skull for a short distance.



Fig. 8.—Small depressed fracture in the squamous portion of the left temporal bone caused by the knuckle of a fist.

#### CAUSES OF DEATH

An attempt was made to ascertain the cause of death in each of the 507 cases so far as it could be determined from the postmortem examination. The clinical data were incomplete and, in most instances, gave only the length of time that the patient survived the injury. This information was too meager to allow an adequate study of the way in which the fatal complication developed during life. The end stages of the process, as disclosed at necropsy, were practically the only reliable facts obtainable, and on these the classification had to be based.

It was obvious that the intracranial conditions found at postmortem examination were not necessarily identical with the intracranial condi-

external parietal and temporal areas suffered most and showed some deep lacerations of this type (fig. 10). In a few instances, comminuted fractures in the frontal region caused extensive mangling of the orbital convolutions of the frontal lobes. A few posterior composite fractures at times lacerated the lateral occipital areas rather severely, but, on the whole, this was rare, as the sharply curved occiput is not easily bent by violence. In one case, the cerebellum was severely torn by a composite fracture in the posterior fossa, so extensively that death resulted from the subsequent intracranial hemorrhage.

(2) Lacerations of the brain were designated as *contre-coup* when it was evident that they were produced by a force which fractured the skull at the point of impact and at the same time caused the brain to be lacerated by violent contact with the opposite side of the cranium. *Contre-coup* lesions, therefore, were found on the side of the head opposite the one on which the fracture took its origin.

The *contre-coup* laceration generally occurred when the skull as a moving object struck violently against a surface. LeCount and Apfelbach<sup>1</sup> explained this mechanism by the fact that the motion of the head would cause the brain to lag behind the more rapidly moving cranium, and at the moment of impact the brain would be closer to the cranial bones opposite to the place where the violence was applied. The axis of the skull would be shortened abruptly at right angles to the plane of impact, and this would lacerate the brain against the opposite side of the skull. Most of the *contre-coup* lesions were undoubtedly produced in this fashion, and the essential factor seemed to be that the head was in motion or free to move at the time of casualty.

*Contre-coup* lesions never occurred when the skull was held motionless at the time of fracture. This point was also duly emphasized by LeCount and Apfelbach. It was well illustrated in the forty fractures produced by an automobile wheel crushing the head of the deceased against the roadway—cases in which motion was not imparted to the head by the violence. Sometimes a few direct lacerations of the brain resulted, but no unmistakable *contre-coup* laceration was identified. The same point was also shown in a man who was struck with a table leg as he lay with his head on a pillow. There was an extensive fracture and a direct laceration at the point of impact, but a laceration on the opposite side was not present. The head was not free to move, and the *contre-coup* mechanism could not work.

The location of *contre-coup* lacerations depended mainly on the part of the skull that was fractured, and it was noticed that they tended to occur in fairly well defined areas, namely, the under and outer sur-

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1. LeCount, E. R., and Apfelbach, C. W.: *Pathologic Anatomy of Traumatic Fractures of Cranial Bones and Concomitant Brain Injuries*, J. A. M. A. 74:501 (Feb. 21) 1920.

tions present in the living subject. As information about the latter was lacking, it was difficult in many instances to estimate the factors responsible for the fatal result. The cause of death, therefore, except in well marked cases, could not be divided into hard and fast categories, and the classification was principally valuable in that it offered a convenient outline for a review of the subject. The classification shown in table 3 was used:

*Deaths from Cerebral Concussion.*—Whenever the head is severely injured, a state of shock characterized by unconsciousness is immediately produced, which has been called cerebral concussion. All that can be said about this condition, as far as its etiology is concerned, is that the violence in some way jars the brain, and that the cerebral centers are depressed. It must be regarded solely as a clinical entity with a pathologic basis which our present methods of examination cannot demonstrate.

TABLE 3.—*Causes of Death*

Cerebral concussion .....	139
Exhaustion .....	14
Secondary pneumonia .....	27
Cerebral compression, lacerations of the brain and subdural hemorrhage..	156
Cerebral compression and extradural hemorrhage.....	61
Meningitis and other septic conditions.....	48
Operation .....	4
Epilepsy .....	3
Other injuries .....	30
Natural causes .....	25

As a rule, the more extensive the fracture of the skull or the bigger the injury of the brain, the more profound is the degree of cerebral concussion. Fatal cases, however, occur without any fractures of the skull and without any visible evidence of brain injury. Evidently, there is not any necessary connection between the concussion and the actual physical lesions in the cranial organs.

The seriousness of the concussion depends on the severity of the violence and on the vitality of the person injured. Even in a healthy person, an extreme grade of violence will cause death in a few minutes. In one who is sick, senile, alcoholic or in other respects below par physically, a slight injury may be just as fatal. Others, however, rally against the shock and recover consciousness rapidly, although at times the ill effects of the condition may remain for several hours.

In the series of 507 cases, deaths from cerebral concussion occurred in 139. The majority of these patients died during the first hour after the injury, and none survived more than ten hours. The figures were as follows: deaths in a few minutes, 86; deaths in from one to four hours, 34; deaths in from five to ten hours, 11; unknown duration, 8.

The age incidence was not anything extraordinary and is recorded in table 4.

faces of the frontal and temporosphenoidal lobes. The brain rested directly on the dura in these areas, and, because of its close proximity to the skull, was easily lacerated by the contre-coup violence accompanying posterior or lateral fractures. The brain injury was often severe and was attended by fatal intracranial hemorrhages.

When the impact was in the posterior region of the skull, the under surfaces of the two frontal and two temporosphenoidal lobes were usually lacerated, sometimes all four, sometimes three, two or even one (fig. 11). There was no regularity as the extent of the involvement.

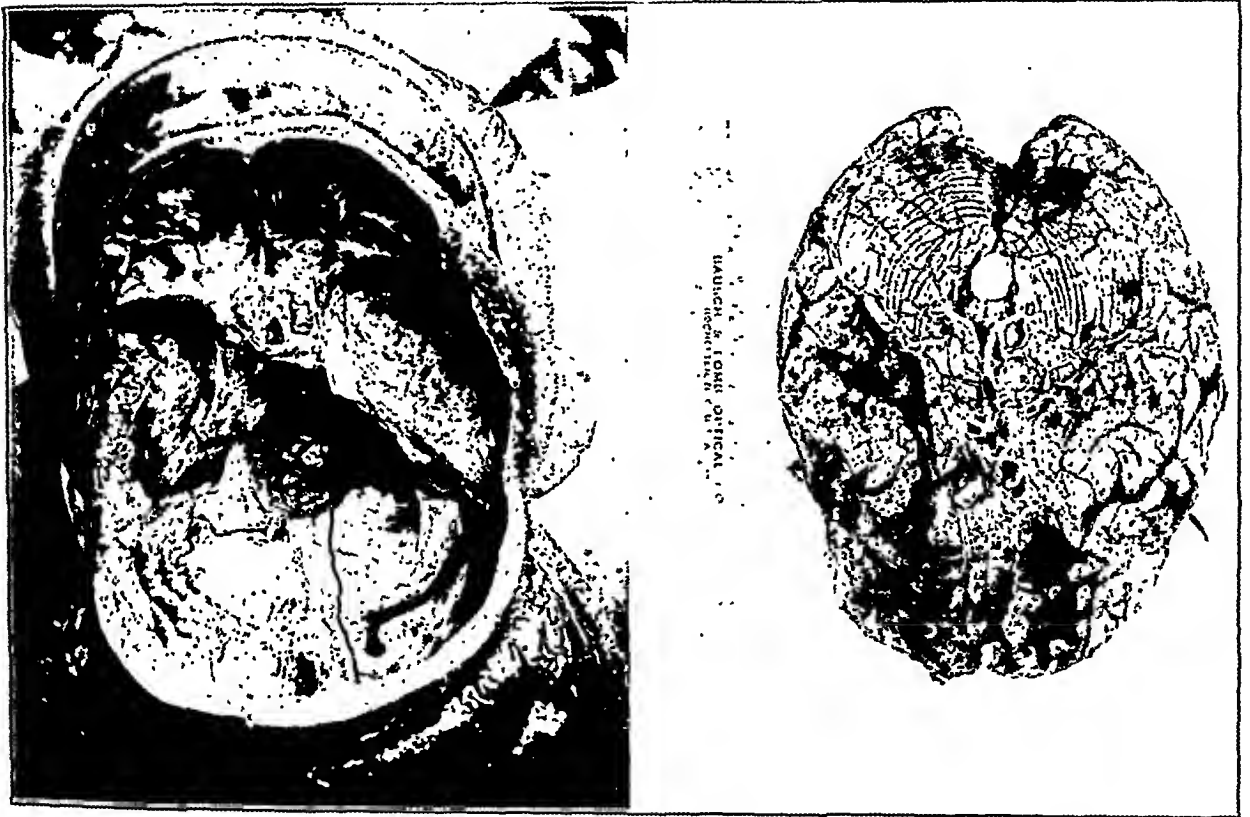


Fig. 11.—Posterior linear fracture of the base of the skull accompanied by broad shallow contre-coup lacerations of the under surface of the left temporal lobe and both frontal lobes.

At times, the anterior tips of the lobes would suffer instead. In other instances, the lateral surfaces on one side would be injured, especially if the point of impact in the occiput was a little to one side of the median line.

A lateral impact generally produced a contre-coup laceration on the opposite temporosphenoidal lobe, either on the lateral aspect or on the under surface of the lobe. Not infrequently, this was combined with a direct brain laceration on the side of the fracture.

The casualties which produce the concussion were, in general, of the more severe types.

It was evident that the more severe fractures, as represented by the composite type, outnumbered the less extensive varieties in the ratio of over 3:1. Fractures in the posterior part of the skull were relatively numerous. Severe lacerations or bruises of the brain were also present in most cases, but they were entirely lacking in sixteen.

The variety of lateral composite fracture which was produced by the crushing force of an automobile wheel occurred in thirty-four cases. Most of the victims were children under 10 years of age. As a rule, this injury was rapidly fatal.

TABLE 4.—Deaths Caused by Cerebral Concussion

Age Incidence			
Years	No. of Cases	Years	No. of Cases
1 to 10.....	25	40 to 50.....	28
10 to 20.....	8	50 to 60.....	24
20 to 30.....	17	60 to 70.....	10
30 to 40.....	16	70 to 80.....	2
Casualty Incidence			
Automobile accidents.....	72	Knocked down in assault....	2
Street car accidents.....	7	Struck by moving object....	1
High falls.....	12	Struck by falling object.....	3
Low falls.....	14	Struck by blunt instruments	2
Falls down stairs.....	12	Unknown casualty.....	12
Thrown down in assault....	2		
Different Types of Fracture			
Vault and base fractures:			
Posterior linear fractures.....			25
Posterior composite fractures.....			37
Lateral linear fractures.....			5
Lateral composite fractures.....			51
Anterior linear fractures.....			2
Anterior composite fractures.....			9
Vault fractures:			
Composite fractures .....			10

Alcohol was found by chemical examination in the brain and liver in forty of the 139 cases of cerebral concussion, or in a ratio of 28.6 per cent. Alcoholism and casualty have always been connected closely, and the action of the drug on the central nervous system of the injured person may exert a threefold influence on the trauma: First, the movements of an intoxicated man are incoordinated, and he is prone to blunder into accidents; second, the anesthetic action of the drug has a tendency to mask the symptoms of the injury and so render the diagnosis difficult; third, its depressing action on the vital nervous centers tends to emphasize the depressing effect of cerebral concussion, and death is likely to occur under a moderate degree of violence. Alcohol was also found in the viscera of skull fractures of persons who died of some cause other than concussion. However, owing to the fact that many of these patients lived so long that all the alcohol in the body had been excreted at the



Occasionally a lateral fracture was associated with a contre-coup bruise on the vertex of the brain in the midline near the coronal suture. This lesion was rarely dangerous in itself, but not infrequently accompanied tearing of the tributaries of the superior longitudinal sinus, which will be discussed later. Another effect of lateral violence was the presence of small pin-point hemorrhages in the corpus callosum, probably caused by impact against the falx cerebri. This also was of minor importance.

Force applied to the anterior part of the skull rarely produced a contré-coup lesion; when such a lesion was produced, it was only of slight grade. The occipital lobes and the cerebellum occasionally showed slight contusions, but none of these were significant.

TABLE 7.—*Deaths Caused by Cerebral Compression, Lacerations of the Brain and Subdural Hemorrhage*

Age Incidence			
Years	No. of Cases	Years	No. of Cases
1 to 10.....	3	40 to 50.....	40
10 to 20.....	1	50 to 60.....	32
20 to 30.....	14	60 to 70.....	16
30 to 40.....	19	70 to 80.....	7
Duration of Clinical Course			
1 to 6 hours.....	32	4 to 6 days.....	5
7 to 12 hours.....	27	6 to 8 days.....	7
13 to 24 hours.....	21	8 to 10 days.....	5
1 to 2 days.....	10	14 days.....	2
2 to 4 days.....	14	Unknown.....	9
Casualty List			
Automobile accidents.....	31	Falls down stairs.....	23
Street car accidents.....	7	Knocked down, assault.....	5
Bicycle accidents.....	1	Hit by moving object.....	2
High falls.....	9	Hit by blunt instrument.....	3
Low falls.....	14	Unknown casualty.....	37

Impact directly on the vertex of the skull at times resulted in the contre-coup lacerations of the orbital convolutions of the frontal lobes or on the under surface of the temporal lobes.

Sometimes recent brain lacerations were found at necropsy when fracture of the skull was not present. They were invariably produced by contre-coup violence, usually resulting from a fall, and they were occasionally followed by a fatal subdural hemorrhage. The point of impact could be located by the scalp wound. Cases of this kind, however, were not included in this series and are mentioned only to indicate that brain lacerations were not invariably dependent on fractures of the skull.

(c) Types of Subdural Hemorrhages and Lacerations of the Brain Causing Death by Cerebral Compression: The deaths in this category were due to cerebral compression caused by (1) blood in the subdural space or (2) laceration of the brain. One hundred and thirty-two deaths were caused by subdural hemorrhages and twenty-four by lacerations of the brain.

time of death, the figures are not presented here. The patients whose accidents came under the category concussion lived only a few hours at the most and were the most suitable group for the consideration of the incidence of alcoholism in skull fractures.

*Deaths from Exhaustion.*—Fourteen persons with fracture of the skull lived from one to twenty days; at necropsy, an obvious cause of death could not be found. Many of these were elderly persons or people in a low state of vitality. These were classified as cases of death caused by exhaustion. The slow decline was considered the result of the concussion incurred at the time of the injury. The patients rallied against the shock to a certain extent, but the central nervous mechanism had somehow been injured by the jarring, and the vitality of the person was

TABLE 5.—*Deaths from Exhaustion*

Age Incidence			
Years	No. of Cases	Years	No. of Cases
1 to 10.....	1	60 to 70.....	4
30 to 40.....	2	70 to 80.....	3
40 to 50.....	2	80 to 90.....	1
50 to 60.....	1		
Casualty Incidence			
Automobile accidents.....	7	Thrown down, assault.....	1
Street car accidents.....	1	Hit by blunt instrument.....	1
Falls down stairs.....	3	Hit by falling object.....	1
Vault and Base Fractures			
Posterior linear fractures.....			3
Posterior composite fractures.....			1
Lateral linear fractures.....			3
Lateral composite fractures.....			6
Anterior composite fractures.....			1

not sufficient for him to throw off the depressing effects of the violence. In this group four persons lived from one to two days after being injured; two persons lived from two to three days; three persons, from four to six days; five persons, from nine to twenty days.

The composite fractures outnumbered the linear fractures in the proportion of 8 to 6. Among the lateral composite group was a crushing fracture caused by an automobile in a boy, aged 8, who lived for four and one-half days after the accident. Lesions of the brain were present in all instances, but in only one was the lesion of any significance. Lobular pneumonia was not found, nor was there any obvious reason for the patient's death besides the fractured skull.

In one instance, a contusion of the cerebral cortex contributed to the fatal termination. This was in a man, aged 40, who had been struck in the right parietal region with an iron bar. A depressed fracture with a linear extension in to the right middle fossa resulted from the blow, causing a broad bruise of the motor area of the right cerebral

(1) A case was listed as subdural hemorrhage whenever it was apparent that there was enough hemorrhage in the subdural space to produce intracranial pressure.

The majority of patients died within twenty-four hours, but others survived for several days.

The location of the fracture and the cause and extent of the subdural hemorrhage are shown in table 8. The subdural hemorrhages are classified as unilateral, in which the hemorrhage was in one subdural space, and bilateral, when both subdural spaces contained blood. The words direct and contre-coup indicate whether the source of the

TABLE 8.—*Fractures and Intracranial Lesions Causing Subdural Hemorrhage*

Origin of the Subdural Hemorrhage	Type of Fracture								
	Posterior Linear	Posterior Composite	Lateral Linear	Lateral Composite	Anterior Linear	Anterior Composite	Vault Linear	Vault Composite	
Unilateral Subdural Hemorrhages:									
Contre-coup lacerations of brain .....	20	18	20	9	0	0	0	0	67
Direct lacerations of brain .....	0	3	6	8	0	0	1	1	19
Direct and contre-coup lacerations of brain, combined .....	0	0	0	1	0	0	0	0	1
Tearing of dura and middle meningeal artery .....	0	0	0	1	0	0	0	0	1
Injury of old adhesion of brain to dura .....	0	0	0	0	1	0	0	0	1
Torn vein, unilateral .....	0	0	0	0	0	1	0	0	1
									— 90
Bilateral Subdural Hemorrhages:									
Contre-coup lacerations of brain .....	12	6	0	0	0	0	0	0	18
Direct lacerations of brain .....	0	0	0	0	0	2	0	0	2
Direct and contre-coup lacerations of brain, combined .....	1	0	6	10	0	0	3	0	20
Contre-coup lacerations of brain and torn dural vein .....	0	0	1	0	0	0	0	0	1
Torn venous tributaries of dural sinus .....	0	0	0	0	0	1	0	0	1
									— 42
	33	27	33	20	1	4	4	1	132

hemorrhage was from direct or contre-coup lacerations, and, whenever the source was from some other lesion, that point is sufficiently designated. It was found in all categories that right and left lesions were equally balanced; consequently, the point is not shown on the table.

The casualty and age tables did not contain anything significant.

An analysis of the fracture sites and the cause of the subdural extravasation, however, brought out some interesting points. The fractures occurred most often on the posterior and lateral portions of the skull, with comparatively few involving the anterior and vault regions. The hemorrhages were caused by contre-coup lacerations in eighty-five cases, by direct lacerations in twenty-one cases and by contre-coup and direct lacerations combined in twenty-one cases. The other intracranial injuries which caused this kind of bleeding were few in number and will be considered later.

cortex. The brain lesion produced numerous convulsive seizures, and death from exhaustion followed after a stormy course of six days.

*Deaths from Terminal Lobular Pneumonia.*—Persons with fractures of the skull who survive their injuries more than two days not infrequently develop lobular pneumonia as a terminal condition. This was shown at necropsy in fifty-nine patients out of the total of 507, but thirty-two of these died obviously of another complication, such as intracranial hemorrhage or suppurative meningitis. The other twenty-seven, however, did not show any other fatal lesions either in the head or in the rest of the body, except the terminal pneumonia.

Anatomically, the pneumonia was of the hypostatic lobular type, for the process was generally located in the posterior portions of the lungs. In the early stages it was often seen in the form of small, granular, gray-red areas of consolidation grouped around the small bronchioli. Later, these areas tended to coalesce, and a pneumonia similar to the lobar type was the result.

Two persons lived from from twelve to twenty-four hours after the fracture; five lived for from one to two days; nine, from two to four days; seven, from four to six days; three, from seven to nine days. An unknown person in a hospital lived eight hours.

Pneumonia usually developed after the second day, but some cases ran a slightly more rapid course. In the more acute types the question arose as to whether it was not possible that the lung condition might have antedated the fracture of the skull. This was not always easy to decide. If blood was inhaled, or the patient was exposed to cold, it was not unusual for pneumonia to develop rapidly. It was also common for many persons to have a "walking" pneumonia for several days, so that they could readily fracture the skull after the lung inflammation was developed fully.

The age incidence is shown in table 6.

The age incidence made it evident that the majority of the patients were middle aged and elderly persons. Their reaction to the trauma was similar to that described in fractures of the neck of the femur in the aged. The patients were never able to rally against the primary shock, but sank to the terminal hypostatic pneumonia.

The primary concussion with its accompanying state of unconsciousness undoubtedly played an important rôle in the development of the inflammation of the lung. There were, however, numerous traumatic intracranial lesions accompanied by hemorrhagic extravasations, which contributed something to the downward course. Twenty-three patients had a laceration of the brain of some kind, and the four who did not showed large hematomas either on the scalp or on the eyelids. Six patients had small extradural hemorrhages. None of these injuries in themselves would have proved fatal, though it is not unlikely that the

The posterior fractures were most likely to result in contre-coup lacerations. In only three were serious direct lacerations alone present, and in these cases the lateral occipital regions were injured by an extensive composite fracture. In one case, a direct laceration and a contre-coup laceration on opposite sides caused a bilateral hemorrhage.

Lateral fractures caused forty-five unilateral subdural hemorrhages, of which twenty-nine were caused by contre-coup lacerations, fourteen by direct lacerations, one by a direct and contre-coup laceration in the same cerebral hemisphere and one by the tearing of the dura and a branch of the middle meningeal artery. Bilateral subdural hemorrhages occurred in seventeen instances, of which sixteen were the result of a direct laceration on the side of the fracture combined with a contre-coup laceration on the opposite side. The other case was the result of the tearing of the small tributary veins of the longitudinal sinus near the coronal suture, combined with a contre-coup laceration.

In one instance, the dura and a branch of the middle meningeal artery were torn by a fragment of bone, and profuse hemorrhage into the subdural space resulted. This was unusual, as most tears of the middle meningeal artery bled extradurally. However, the firm attachment of the dura to the cranium prevented an extradural extravasation, and the severe comminuted fracture in the temporal region caused the bleeding artery to point through the dural tear into the subdural space. The blood spurted upward and was found as a large compact clot, 220 Gm. in weight, compressing the parietal convolutions inward.

The vault fractures were all located laterally and caused unilateral subdural hemorrhages in two instances from direct lacerations and bilateral subdural hemorrhages in three instances from direct and contre-coup lacerations.

Fractures in the anterior region caused unilateral subdural hemorrhages in two instances, one from the tearing apart of old adhesions of the brain to the dura by the recent violence, and the other from a complete tear of a vein which connected the temporal lobe of the brain with the dura of the middle fossa. In both these instances the violence was applied just to the right of the midfrontal region in such a way that the skull was shortened in the diagonal diameter from front to back and from right to left. The brain in the left temporal region was forced to slide backward along the inside of the skull, and this produced the tearing of the aforementioned vessels.

Anterior fractures caused bilateral subdural hemorrhages in three instances. In two, a comminuted fracture of both orbital plates extensively lacerated the adjacent portions of the frontal lobes and produced the bleeding. In the other case, the force struck the lateral portion of the right frontal region, shattered the right orbit and imparted a violent lateral oscillation to the brain. The tributary veins which run

continual absorption of toxic products from the areas of blood extravasation had a depressing effect on the vitality of the patient.

*Deaths caused by Cerebral Compression, Lacerations of the Brain and Subdural Hemorrhage.*—(a) Pathologic Anatomy of Brain Injuries: Injuries of the brain are the most common complications produced by fractures of the skull. In the series of 507 patients, the brain was unharmed only forty-two times, while the remaining 465 patients had a cerebral lesion of some kind. The majority of these, however, did not produce any untoward effects, and it was estimated that only from 33 to 40 per cent played an important rôle in causing the death of the patient.

TABLE 6.—Deaths from Terminal Lobular Pneumonia

Age Incidence			
Years	No. of Cases	Years	No. of Cases
20 to 30.....	1	60 to 70.....	8
30 to 40.....	2	70 to 80.....	6
40 to 50.....	4	80 to 90.....	1
50 to 60.....	5		
Casualty List			
Automobile accidents.....			15
Street car accidents.....			2
Low falls.....			2
High falls.....			4
Unknown.....			4
Fracture Distribution			
Vault and base fractures:			
Posterior linear fractures.....			2
Posterior composite fractures.....			1
Lateral linear fractures.....			6
Lateral composite fractures.....			7
Anterior linear fractures.....			4
Anterior composite fractures.....			3
Vault fractures:			
Composite fractures.....			2

The injuries of the brain were mainly on the surface of that organ and resulted from the soft cerebral tissue coming in violent contact with the skull. All degrees of the lesion were present. A slight impact caused a localized subarachnoid hemorrhage by rupturing small vessels in the subarachnoid space. A greater violence bruised the cortex but left the arachnoid intact. Sometimes the force was severe enough to tear the arachnoid membrane and to lacerate the brain tissue superficially. At other times the tear was deeper, and considerable destruction of the gray matter was the result. In a few cases a vessel in the white matter near the surface was ruptured, and a blood cyst was found; some of these contained an ounce of blood clot; they usually opened into the subdural space, though sometimes they communicated with the lateral ventricles or formed closed cavities in the white or gray matter.

The torn vessels in recent lacerations bled into the subdural space in varying degrees. When the hemorrhage was slow, clots were formed

from the brain to the superior longitudinal sinus were torn on both sides near the coronal suture and bled profusely into the subdural spaces. These same tributary veins are not infrequently ruptured during a boxing match by a heavy blow applied to the side of the head, which, however, does not necessarily cause a skull fracture. The essential factor in the production of the venous rupture is the oscillation of the brain from side to side in such a manner that the venous tributaries near the vertex are under special stress.

In thirty-six cases of subdural hemorrhage, the extravasated blood was carefully detached from the dura and brain lacerations and weighed. When the hemorrhage was bilateral, the blood in both subdural spaces was combined, and the weight of this was taken.

The average weight of the subdural hemorrhage was 61.1 Gm.

When the clinical course was short, the clots were usually smaller, but patients who died within six hours often showed some rather large hemorrhages, one unilateral extravasation reaching the size of 110 Gm.

TABLE 9.—*Weight of the Clots in Subdural Hemorrhages*

Gm.	No. of Cases	Gm.	No. of Cases
15.....	1	70.....	3
20.....	1	80.....	5
25.....	3	90.....	1
30.....	4	100.....	2
40.....	2	110.....	1
50.....	7	130.....	1
60.....	4	220.....	1

The interesting feature was that the small subdural hemorrhages produced just as acute evidences of pressure as the large ones. Of course, the subdural spaces were of different capacities, but the variation in capacity, as represented by the weights of the subdural clots, was much greater than any normal variation. The intracranial organs, however, were not in a normal state after a severe skull fracture, and some conditions of the brain were often present that probably reduced the capacity of the subdural spaces. This is treated in more detail subsequently.

2. Twenty-four fractures of the skull showed severe brain lacerations which resulted in cerebral compression without causing any subdural hemorrhage worthy of note.

The lacerations of the brain were extensive, but they differed in their anatomic characteristics. Some were shallow, showing a depth about the thickness of the cerebral cortex, but covered a wide area, often as much as from 6 to 8 square inches. In all probability, they caused the intracranial tension because the traumatized brain tissue and adherent blood clot gave rise to a swelling of the brain substance around the site of the laceration from local circulatory disturbances. Several cases lasted for from two to five days, and an uninjured zone of cerebral

which adhered to the surface of the laceration and thus were localized in the injured area. A more rapid hemorrhage tended to fill the corresponding subdural space.

The subdural hemorrhages were either unilateral or bilateral. When unilateral, the blood was confined strictly to the subdural cavity surrounding the injured cerebral hemisphere. The hemorrhage never extended beyond the limits of this space, either to the opposite subdural space or below the tentorium. As the hemorrhage grew in size, the blood forced the brain over against the opposite vault of the skull, causing a noticeable flattening of the cerebral convolutions in this region. The convolutions on the side of the hemorrhage, however, were well marked and stood out prominently, although the arachnoid was pressed closely to the cortical surface. In those cases in which the skull was removed so that the underlying membranes were not torn, the dura was distended and tense from the pressure within.

The subdural hemorrhage was bilateral when lacerations occurred on both cerebral lobes. Either the two spaces contained approximately the same amount of blood or one side yielded a much greater amount than the other. The hemorrhages were not uniform in size, and there was not necessarily any relation between the nature of the laceration and the quantity of blood in the subdural space. With two lacerations of similar degree on either cerebral hemisphere, one might bleed a little, while the other might produce a profuse extravasation. Flattening of the cerebral cortex was not prominent in bilateral hemorrhages unless one side showed a large quantity of blood while the other contained only a small amount. However, when both subdural spaces were distended by the extravasation, the brain was pressed downward. Occasionally this produced flattening of the pons against the basilar process and a circular furrow of the inferior surface of the cerebellum by pressure against the rim of the foramen magnum.

Subdural hemorrhages below the tentorium were caused by cerebellar lacerations and were rather rare. Most of these were insignificant.

Subarachnoid hemorrhages were also found, and some of them were profuse. In a few instances, the space around the circle of Willis was distended by blood, which took its origin from some ruptured vessel in that network. These extravasations were spontaneous in most cases, usually were fatal and often were found without a history or evidence of injury of the head, but a few were undoubtedly traumatic. It was always difficult to make a distinction if a fracture was present.

Most subarachnoid hemorrhages of unquestionable traumatic origin were found on the upper portions of the frontal lobes. The blood was usually extravasated under the membrane from brain injuries near the tip of the lobe. The subarachnoid space was roomy on the cerebral vault but was closely applied to the convolutions at the base, so that the



substance immediately adjacent to the broad surface lesion was swollen, translucent and obviously edematous. This swelling was sufficient to produce a definite intracranial tension.

Some lacerations, however, extended into the brain substance, forming large cavities near the surface, from 1 to 2.5 inches in diameter, which contained 20 to 30 Gm. of blood clot (fig. 12). The cause of the cerebral compression was obvious. In four instances, the cavity extended into the ventricles of the brain and filled them with blood clot.

TABLE 10.—*Cases of Brain Lacerations Which Caused Cerebral Compression*

Age Incidence			
Years	No. of Cases	Years	No. of Cases
1 to 10.....	2	40 to 50.....	7
10 to 20.....	1	50 to 60.....	5
20 to 30.....	1	60 to 70.....	2
30 to 40.....	6		
Casualty Incidence			
Automobile accidents.....	12	Falls down stairs.....	2
Low falls.....	2	Assault by blunt instrument	2
High falls.....	1	Unknown.....	5
Duration of Clinical Course			
1 to 6 hours.....	3	4 days.....	1
7 to 12 hours.....	8	5 days.....	2
13 to 24 hours.....	8	Unknown.....	1
2 days.....	1		

TABLE 11.—*Location and Variety of Brain Lacerations Causing Cerebral Compression*

Types of Lacerations	Types of Fracture			
	Posterior Linear	Posterior Composite	Lateral Composite	Vault Composite
Unilateral contre-coup lacerations.....	2	3	1	6
Bilateral contre-coup lacerations.....	5	4	1	11
Direct laceration, cerebrum.....	..	..	3	3
Direct laceration, cerebellum.....	..	1	..	1
Direct and contre-coup lacerations.....	..	..	2	2
Direct and contre-coup laceration, unilateral.....	..	1	..	1
	7	9	7	24

Intraventricular hemorrhages: contre-coup lacerations of cerebrum, 3; direct laceration of cerebellum, 1.

Death usually occurred soon—within twenty-four hours. One patient, however, survived for four days. Three lacerations opened into the lateral ventricles, while the fourth was caused by a laceration of the cerebellum which bled into the fourth ventricle.

(d) Conditions of the Brain in Cerebral Compression: The first few hours immediately following a severe fracture often produced clinical signs of increased intracranial pressure, and cases which came to necropsy in this period showed anatomic evidence of this condition in flattened convolutions, engorged cerebral blood vessels and other

blood spread profusely over the vertex of the brain and rarely spread down on the under surfaces. This lesion probably produced symptoms but in itself was not necessarily lethal.

In a few cases, the laceration opened into one of the ventricles of the brain, so that the cavity of the brain contained blood and blood clot, sometimes enough to cause an appreciable distention, such as would occur in internal hydrocephalus.

In some instances, small hemorrhages of traumatic origin were found in the pons and also in the basal nuclei underneath the floor of the lateral ventricles. These lesions were composed of multiple extravasations of blood varying in size from that of a pinhead to that of a pea, which sometimes tended to coalesce and form larger areas. Thus they could be distinguished from spontaneous hemorrhages in similar locations, as the latter usually appeared as large solitary clots. At times, the distinction was difficult, for a spontaneous apoplectic stroke could



Fig. 9.—Cross-section of the pons showing small hemorrhages of traumatic origin.

occur at the same moment that the skull was fractured. As a rule, however, the traumatic pontile lesions were associated with severe fractures in the back part of the skull which in some way violently compressed the brain stem. Likewise, violent impacts near the external angular process of the frontal bone had some influence in producing the multiple lesions in the basal cerebral nuclei. Just how much of a factor these multiple hemorrhages were in causing the death of the patient is a question, because the degree of concussion was so severe that other symptoms were overshadowed. Some of the pontile hemorrhages, however, were large enough to cause distention of that area, and it was conceivable that this produced considerable trouble in itself (fig. 9).

Different stages in the healing of brain lacerations were often observed. Shortly after the injury, the lacerated area was bright red, but its color gradually changed to brownish red, then to brown and finally to a shrunken tan area known as "plaque jaune." The process was a gradual transformation of the blood pigment, the absorption of



necrotic débris and the development of a characteristic granulation tissue, with the final healing by scar tissue. The stages were analogous to the healing of wounds elsewhere in the body although, of course, not identical, as the brain had a characteristic cellular reaction which differed from any other tissue.

In some instances, adhesions between the brain and dura were found around the site of old lacerations. Granulation tissue, usually vascular, had grown into the injured area and had joined the two surfaces. Some of these adhesions were large and most often were found near the frontal and temporal regions in which they were always a potential seat of disturbance in ways which will be considered later.

Changes were also described in many subdural hemorrhages when they were seen long after the injury. A small hemorrhage might disappear and only a diffuse spotted, tan pigmentation on the inside of the dura would be left to indicate its presence. A somewhat larger extravasation was found in the later stages as a tan fibrinous membrane closely attached to the dura. More often, in persons who died from large extravasations, the clots varied in color from a wine red to a brownish red or cinnamon brown, and were more or less attached to the dura. Microscopic examination often demonstrated the fact that the dura showed a distinct inflammatory reaction against the extravasated blood.

(b) Relation of Brain Lacerations to Fractures of the Skull: Brain lacerations were classified according to their method of production into (1) direct lacerations and (2) contre-coup lacerations.

(1) Direct lacerations were so designated because the surface of the brain was torn directly by the inward depression of the sharp fracture edges which often inflicted a corresponding tear on the adjacent dura. The form and position of the laceration, therefore, depended on the variety of the fracture.

Linear fractures produced furrows of different dimensions which marked the course of the fissure in the skull on the brain. Important lesions of this type were most often found on the lateral aspect of the parietal and temporal lobes, for the broad and flat expanse of skull which covers this area is easily depressed by force. The cerebral laceration was occasionally severe enough to produce a fatal subdural hemorrhage. Longitudinal linear fractures of the posterior fossa often furrowed the under and outer surfaces of the cerebellar lobes. In a similar fashion, linear fractures of the anterior fossae occasionally caused a linear laceration of the orbital convolutions of the frontal lobes. These, however, as a rule, were not productive of any alarming complications.

Composite and depressed fractures also produced characteristic lacerations in the form of fossae and pits of various sizes and shapes. While they occurred almost anywhere on the surface of the brain, the

Subdural hemorrhages, however, that lasted several days often showed hypostatic bronchopneumonia of the type already described.

*Deaths Caused by Cerebral Compression and Epidural Hemorrhage.*—In the series of 507 cases, epidural or extradural hemorrhage was described in 106. Forty-five of these blood clots were small and were not considered important. The remaining sixty-one, however, were large enough to prove fatal through cerebral compression.

All epidural hemorrhages in fractures of the skull are caused by the sharp edges of the broken bone lacerating a vessel on the outside of the dura. The torn vessel bleeds in between the dura and the skull and pushes the dura inward against the adjacent portion of the brain,



Fig. 13.—Middle meningeal hemorrhage in the right posterior parietal region. The lateral composite fracture and part of the craniotomy opening are also shown on the right side of the skull.

causing compression of that area. The bleeding occurs only where the line of fracture extends and is never found elsewhere. The vessels most often lacerated are the branches of the middle meningeal artery. In rare instances, the lateral venous sinus and the anterior meningeal artery are involved.

The middle meningeal artery is in a good position to be lacerated, as it is placed on the outside of the dura and lies in grooves on the inside of the skull. It enters the skull through the foramen spinosum in the middle fossa and runs laterally a short distance before it divides into anterior and posterior branches, which spread in a dendritic fashion over the temporal and parietal regions of the vault. It is, therefore, easily reached by lateral fractures of all kinds.

destructive process. From July 8, 1920, until Aug. 9, 1921, the patient received further radium treatment in the form of the lead tray over the parietal, occipital and temporal regions (total of 24,477 millicurie hours, 3 cm. distance).

Physical examination, April 27, 1922, showed the patient in excellent general condition; there was only slight exophthalmos of the right eye; the sight was normal; the large area in the right parietal region which was originally almost



Fig. 45 (case 73 in table 7).—Sarcoma of fibula; resection; amputation; followed by lung metastases.

completely destroyed was almost entirely filled in with new bone; the occipital region also was normal. He had been attending school all winter and had made two grades. He was given another radium treatment at this time, more as a prophylactic measure than anything else. The toxins had been kept up with occasional intervals of rest, since the time of my first observation. The improvement was continuous, the patient gained in weight, and at the present time,

patient was admitted to the Memorial Hospital, October 27, where he received 10,109 millicurie hours of radium at 7 cm. distance. The family was urged to leave the child in the hospital for further treatment, but as a hopeless prognosis had been given, they took the child home. No further toxins or radium treatments were given.

In the early part of May, 1921, we received a letter from the father of the child stating that the latter was apparently in perfect health and going to school regularly. He was brought to the Memorial Hospital, September 19, when a careful examination failed to reveal any evidence of a tumor in the abdomen or groin, and a roentgenogram of the chest showed no evidence of the metastasis that had been present in the preceding October. The patient was shown at a clinic at the Memorial Hospital to the members of the American College of Surgeons in October, 1924, at which time he was in excellent condition with no evidence of the disease in the groin or abdomen. A roentgenogram taken on the

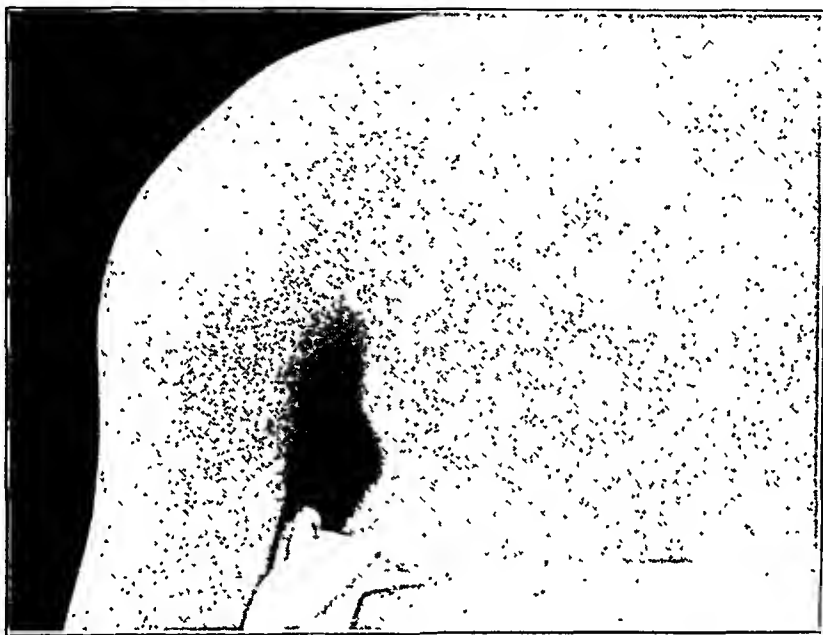


Fig. 48 (case 96 in table 7).—Periosteal sarcoma of humerus. The patient refused amputation and was treated by toxins, roentgen ray and radium. Death occurred from metastases one year later.

same day showed the chest entirely free from metastases. The patient is still well at the present time, July, 1926, six years later.

*CASE 23.—Osteogenic sarcoma of the femur of central and periosteal involvement; round cell, probably endothelioma.*

D. M. S., a man, aged 22, was admitted to the Memorial Hospital, July 20, 1920, having been referred by Dr. Walton Lee of the Pennsylvania Hospital. In October, 1918, the patient sustained a fracture of the left leg; during 1919 he suffered from severe pain and swelling. In March, 1920, he was admitted to the Pennsylvania Hospital and was operated on by Dr. Walton Lee, April 17. The process was found to extend through the larger part of the shaft of the femur, and the larger portion of the bone was removed. The microscopic examination report (Pennsylvania Hospital), March 17, was osteogenic sarcoma of the femur.

Physical examination on admission to the Memorial Hospital, July 20, showed a thickening of the central portion of the shaft and middle portion of the left femur, with considerable enlargement. The clinical and roentgen-ray diagnosis

In this series, fractures in the lateral parts of the skull numbered 233, and epidural clots from the middle meningeal artery of any size numbered fifty-six, so that only a small proportion of fractures resulted in serious laceration of the artery. A reason for this is suggested by the changing relationship between the skull and dura at different periods of life.

In childhood, the bony grooves for the middle meningeal artery are shallow, and the dura is easily separated from the skull. Accordingly, the artery escapes injury except in rare instances. As the person grows older, the dura becomes more and more adherent, and the grooves deepen, so that in old people there is a thick adherent dura and pronounced grooves. Extradural clots are rather infrequent at this age, as

TABLE 12.—*Cases of Cerebral Compression and Epidural Hemorrhages*

Age Incidence			
Years	No. of Cases	Years	No. of Cases
*10 to 20.....	2	50 to 60.....	7
20 to 30.....	13	60 to 70.....	2
30 to 40.....	18	70 to 80.....	2
40 to 50.....	17		
Casualty Incidence			
Automobile accidents.....	5	Knocked down in assault....	3
High falls.....	9	Struck by blunt instrument.	5
Low falls.....	10	Hit by flying object.....	1
Falls down stairs.....	7	Unknown.....	21
Duration of Clinical Course			
1 to 6 hours.....	9	4 days.....	1
7 to 12 hours.....	13	6 days.....	2
13 to 24 hours.....	11	8 days.....	2
1 to 2 days.....	2	Unknown.....	17
2 to 3 days.....	4		

\* Since this paper was written, the author has seen a case of a child, aged 8, who died from an epidural hemorrhage from the anterior branch of the middle meningeal artery. The cause was a comminuted lateral fracture. The condition in children is rare.

the adherent dura prevents excessive hemorrhage. In young adult life and middle age, however, the bony grooves are not so deep, and the dura is adherent just enough to allow laceration of the artery, but not to the extent that it prevents its separation from the bone by the violence. Most extradural hemorrhages are found at these ages, as shown in table 12.

The decade from 30 to 40 years contained the greatest number of cases.

One of the cases, that of a person aged 70 years, was noteworthy in that the skull was the seat of a pronounced osteitis deformans. The bone was thick but soft and pliable, while the dura was not firmly adherent to the skull. Conditions were therefore favorable for the epidural clot which developed.

The duration of the clinical course was rather variable, over one half of the patients dying inside of twenty-four hours. In other instances,



*Deaths Caused by Injuries Elsewhere in the Body.*—Thirty patients showed fractures of the skull of moderate degree which were accompanied by severe injuries in other portions of the body. Death was obviously the result of the latter.

TABLE 17.—Cases of Epilepsy

Age, Color, Sex	Casualty	Lesions of Skull at Necropsy	Lesions of Brain	Cause of Death	Duration after Primary Injury
White man 45 years	Low fall	Decompression window, right frontal region	Huge adhesion of right frontal lobe to site of operation	Generalized epileptiform convulsions	2½ years
Colored man 52 years	Assault with hatchet	Decompression window, left frontal region	Huge adhesion of left frontal lobe to old operative area	Generalized epileptiform convulsions	1½ years
White man 68 years	Unknown	Healed depressed fracture, left posterior region	Contre-coup laceration of right frontal lobe adherent to adjacent dura	Epileptiform convulsions	Unknown, but of some duration

TABLE 18.—Cases of Injuries Elsewhere in the Body

Casualty Incidence			
	No. of Cases		No. of Cases
Automobile accidents.....	24	Low fall.....	3
Street car accidents.....	1	Unknown.....	1
High fall .....	1		
Age Incidence			
Years		Years	
1 to 10.....	4	40 to 50.....	3
10 to 20.....	4	50 to 60.....	2
20 to 30.....	1	60 to 70.....	2
30 to 40.....	2	70 to 80.....	4
Duration of Clinical Course			
Found dead.....	2	12 to 24 hours.....	1
Minutes.....	10	2 to 3 days.....	1
1 to 6 hours.....	10	6 days.....	1
6 to 12 hours.....	4	25 days.....	1
Location of Fractures			
Posterior linear.....	11	Anterior linear.....	5
Lateral linear.....	10	Vault linear.....	1
Lateral composite.....	3		
None of these cases showed any intracranial lesions of any severity			
Causes of Death			
Shock from severe fractures of spine, ribs, pelvis or bones of extremities.....			12
Internal hemorrhage in chest or abdominal cavity from ruptures of liver, spleen or lungs.....			16
Septic infections from injuries of trunk.....			2

*Deaths Due to Natural Causes Unrelated to Fractures of the Skull.*—There were twenty-five such cases, and all showed slight fractures of the skull. Death was obviously the result of some other condition which did not have any connection with the fracture of the skull.

the patients lingered a few days. A large proportion were found dead, and it was impossible to discover not only how long they lived after the injury, but also what the casualty really was.

Many persons with epidural hemorrhages, especially those found dead or unconscious, showed extraordinarily thin skulls. They were, apparently, fractured by a comparatively slight violence, so that the primary concussion was of short duration or entirely absent. It was not unusual for these persons to wander away from the scene of the accident and to be overcome by rapidly developing cerebral compression some hours later. If found alive, they were either moribund or stuporous, which suggested alcoholic intoxication, and the serious nature of their condition was not recognized. The difficulties of diagnosis not infrequently were increased by the entire absence of any external injury to the head and also by the fact that the deceased was alcoholic. It was probable that the majority of these fractures were caused by falls.

TABLE 13.—*Epidural Hemorrhages and Their Source*

Vessels Ruptured by Fracture	Fractures, Types and Location							
	Poste- rior Linear	Poste- rior Com- posite	Lateral Linear	Lateral Com- posite	Ante- rior Fissure	Ante- rior Com- posite	Vault Linear	Vault De- pressed
Middle meningeal artery, poste- rior branch .....	..	4	11	6	..	..	3	1
Middle meningeal artery, ante- rior branch .....	..	1	5	3	..	..	1	2
Middle meningeal artery, main stem .....	..	..	2	..	..	2	..	..
Middle meningeal artery, branch involved not located.....	..	..	9	4	1	..	1	..
Anterior meningeal artery.....	..	..	..	..	1	..	..	..
Lateral venous sinus.....	3	1	..	..	..	..	..	..
	3	6	27	13	2	2	5	3
								61

The form and location of the hemorrhage varied with the site of the fracture and the vessel that sustained the rupture.

The right and left sides were equally involved and were not indicated in the table.

Lateral fractures were responsible for forty epidural hemorrhages, almost two thirds of the total number, and the middle meningeal artery was the only vessel ruptured. Other fractures occasionally lacerated this vessel, but only when a fracture line extended to the parietal region or the middle fossa. In this connection, it was worthy of note that epidural hemorrhages did not result from the transverse crushing fractures of the skull which have already been described.

The total number of middle meningeal hemorrhages was fifty-six. Of these, twenty-five were identified as arising from the posterior branch, twelve from the anterior branch, four from the main stem in the middle fossa, and fifteen could not be located with certainty.

In six of the cases there were old healed fractures of the skull, easily identified as such at necropsy. Only a small proportion of the healed fractures were found occasionally in the routine postmortem examinations. All of them showed old healed lacerations of the brain of the contre-coup or direct type. None had been subject to operation, and the primary injury had cleared up more or less spontaneously. It was probable that a large proportion of patients with less severe fractures of the skull did recover in this fashion, although it was difficult to determine the exact percentage with any degree of accuracy.

Most of the patients had had a severe general illness at the time the injury was received, and the fracture was merely a minor factor

TABLE 19.—Deaths Due to Natural Causes

Casualty Incidence			
	No. of Cases		No. of Cases
Automobile accidents.....	5	Assaults by blunt instruments	2
Low falls.....	6	Unknown.....	11
Fall down stairs.....	1		
Age Incidence			
10 to 20 years.....	1	50 to 60 years.....	5
20 to 30 years.....	3	60 to 70 years.....	3
30 to 40 years.....	8	90 to 100 years.....	1
40 to 50 years.....	4		
Duration of Clinical Course			
Found dead.....	4	Days.....	4
Minutes.....	7	Old fractures.....	6
Hours.....	4		
Location of Fractures			
Posterior fissure.....	4	Anterior linear.....	7
Lateral fissure.....	6	Anterior composite.....	3
Lateral composite.....	3	Vault linear.....	2
Causes of Death			
Spontaneous cerebral hem-		Illuminating gas poisoning....	1
orrhage.....	3	Pulmonary tuberculosis.....	2
Acute alcoholism.....	7	Erysipelas.....	1
Chronic alcoholism.....	1	Coronary artery disease.....	3
Chronic meningitis.....	1	Rupture of aortic aneurism...	1
Chronic encephalitis.....	1	Lobar pneumonia.....	2
Idiopathic epilepsy.....	1	Obstruction of bile ducts.....	1

in producing the fatal result. It is probable that some of the brain conditions caused symptoms of vertigo and unsteadiness, so that the deceased was made to fall and fracture his skull in this fashion. This was probably true of the three patients who died of spontaneous cerebral hemorrhage.

*Fractures of the Skull in the New-Born and in Infants Under 5 Months of Age.*—The skull of the young infant is entirely different in structure from the skulls of older children and adults. While the cranial bones of the latter are fused, forming a compact rigid case for the brain, the skull of the infant is a pliable sac of bony plates held together by a membrane, so that it is easily distorted by violence. Fractures of the skull in the early months after birth, therefore present peculiarities not characteristic of the lesion in the later periods of life.

The only way to determine the origin of the hemorrhage at necropsy was by a consideration of the fracture lines and the position of the clot, as the tear of the artery could not always be found. In the fifteen undetermined cases, it was not possible to ascertain the site of the rupture even in this way, for the observations were not definite enough.

The middle meningeal hemorrhages occurred on the vault in most instances; only a few were found at the base. Torn posterior branches of the artery generally formed blood clots in the middle and posterior portions of the parietal region. Ruptures of the anterior branches bled outside the dura in the anterior portion of the lateral surface of the vault. Most hemorrhages of the vault were unilateral and showed a circular and ovoid outline, with a sharp rim and a thick center, so that they could be designated as disk, diskus or platter shape. If the artery was lacerated near the base, a small tongue of blood clot occasionally ran from the point of laceration upward to the disk-shaped hemorrhage above. In one instance, the line of fracture extended over the posterior parietal regions from one side to the other and ruptured the posterior branches on each side of the skull, forming two discrete, symmetrically placed, bilateral epidural hemorrhages of equal size.

In some cases, rupture of the anterior branches or the common stem caused an extradural hemorrhage at the base of the skull. The blood clot then developed a globular or egg-shaped form and pressed the under surface of the frontal and temporosphenoidal lobes upward.

In one instance, an anterior fissure fracture lacerated the anterior meningeal artery as it emerged from its foramen, forming a globular hemorrhage which dented the anterior tip of the frontal lobe.

Ruptures of the lateral venous sinus were the results of fracture in the posterior regions, which tore the posterior wall of the sinus. The hemorrhage took an ovoid form and pressed in the cerebellum and occipital lobes. These were especially fatal, as this region of the brain was vulnerable to pressure.

The characteristics of the epidural hemorrhage varied with the size of the clot and the length of time that the patient lived after injury. Hemorrhages of recent origin at necropsy showed friable blood clots, resembling currant jelly, which were easily detached from the dura. Sometimes, when there was a large amount of extravasated blood, about 1 inch thick through its center, it was possible to find separation of the blood clots into layers such as occurs in postmortem clotting. Hemorrhages of longer duration were firm, compact, rusty red and adherent to the dura.

The blood between the dura and bone had an irritant action on the bone, but unfortunately this could not be studied satisfactorily in the material at hand. In the cases that came to necropsy, observations which could be positively identified as the remains of an old extradural hemor-

In the infant, the base of the skull is small in proportion and closely knit and elastic. The vault is relatively voluminous and is composed of five curved, easily bent plates of bone, comprising the two parietal bones, the two halves of the frontal bone and the occipital bone. The dura lines these segments rather loosely, except at the edge of the segment, where it is firmly attached. The bony plates are joined by a thick fibrous membrane which is widened in the midline at each end of the two parietal bones to form fontanels. The larger anterior fontanel is placed at the coronal suture and the smaller posterior at the lambdoid suture.

The parietal bones are most often fractured because they are the most prominent segments of the vault and, therefore, the area most subjected to trauma. They were involved in all five cases of this series, and in all

TABLE 20.—*Fractures of the Skull in Young Infants*

Age, Sex	Casualty	Duration	Fracture	Other Lesions	Cause of Death
New-born; girl	Unknown	2 days	Linear parietal fracture	None	Concussion
3½ months; boy	Hlt by thrown pitcher	2 days	Comminuted parietal fracture	Direct laceration of brain	Effects of concussion
17 hours new-born; girl	Thrown from window	17 hours	Linear parietal fracture	Direct laceration of brain	Effects of concussion
3½ months; boy	Unknown fall?	Unknown	Linear parietal fracture	Direct laceration; contre-coup lacerations frontal lobes; bilateral subdural hemorrhage, 10 Gm.	Cerebral compression
1 month, 4 days; boy	Thrown to floor of taxi	3 hours	Comminuted parietal fracture	Direct laceration; tear of membrane of anterior fontanelle	Concussion

except one, the fractures were confined to this region. In the other case, an extensively comminuted fracture, the frontal bone and part of the anterior fossae were included, together with the parietal plates. This, however, was rather unusual, for generally the base of the skull escapes injury in infants. The membranous attachments of the vault and the mobility of its plates have a tendency to confine the effect of the violence to the bones primarily struck, with but little transmission of the force to other parts of the cranium.

The fractures in the parietal bone depend on the directions of the bony striations which radiate out from the central prominence or boss toward the edge of the bone. The linear fractures occur in the direction of these striations. They appeared as simple straight splits of the bone from the edge to the central prominence in two cases, and in a third the fracture was angular, with the point of the angle at the apex of the prominence. The other two fractures were comminuted extensively.

rhage of any size were not encountered, although occasionally peculiar, milky white, eburnated, roughened areas on the inside of the skull were found, to which the dura was firmly attached. The same observations were not infrequent around the edges of old decompression windows and occasionally in the region of old healed fractures. It was not improbable that these milky white areas were the remains of small epidural blood films which were frequently noted around fractures, and which were caused by the tearing of multiple small communicating vessels when the dura was separated from the bone during the violence.

The epidural clot was detached from the dura and carefully weighed in twenty-five cases. The weights are tabulated in table 14.

The average weight of the epidural hemorrhage was 122 Gm., which is about twice as large as the weight of the average subdural hemorrhage, which was 61 Gm.

There was not any essential correspondence between the weight of the blood clot and the duration of the clinical course, as small and large

TABLE 14.—*Weight of the Epidural Hemorrhage*

Gm.	No. of Cases	Gm.	No. of Cases
40.....	1	120.....	1
50.....	2	130.....	2
60.....	1	140.....	1
70.....	0	160.....	1
80.....	2	170.....	3
90.....	2	190.....	1
100.....	3	200.....	1
110.....	3	300.....	1

hemorrhages were found at all periods. There likewise was not any difference in size between the blood clots that came from the anterior or posterior branches of the middle meningeal artery. However, epidural hemorrhages from the lateral venous sinus were generally smaller than the middle meningeal artery hemorrhages, for the two sinus hemorrhages measured were only 50 and 60 Gm., respectively.

Other lesions were occasionally found in deaths from epidural hemorrhages. Lacerations of the brain were found in fifty-six cases but gave rise to subdural extravasations in only sixteen cases, of which thirteen were caused by contre-coup lacerations and three to direct lacerations. None of them were severe enough to cause a fatal cerebral compression in themselves. In five cases, brain injury of any kind was not visible.

The condition of the lungs was similar to that found in the cases of subdural hemorrhages. Death from cerebral compression occurring soon after an accident was accompanied by marked hypostatic congestion and edema of the lungs, while a longer clinical course sometimes showed a terminal lobular pneumonia.

Lacerations of the brain occurred in four cases as direct lacerations in the region of the fracture, while contre-coup lacerations on the under surface of the frontal lobes occurred only once. In one instance, lacerations of the brain were absent. As a rule, the cerebral lesion was not productive of complications, except in one infant who developed a subdural hemorrhage.

The dura was sometimes torn by the bone, but not invariably, and lacerations of the brain were readily produced without a dural tear.

A tabulation of these cases is given in table 20.

Apparently the cerebral concussion played the most important rôle in causing death. In infants, as in elderly people, however, a slight trauma often had the effect of depressing the central nervous system only to a slight degree, but the organism did not possess enough vitality to throw off the effects of the primary shock altogether. They usually remained for several hours or days until death ensued.

The subdural hemorrhage caused death by compression and, from the postmortem appearance of the blood, had evidently been of many days' duration; the lack of reliable history, however, was a handicap to study of the case.

#### SUMMARY

1. Five hundred and twelve cases which came to necropsy were reviewed in order to study the different conditions that caused death in fractures of the skull.

2. The types of fractures were classified as

*A. Fractures of the vault and base*

(1) Posterior fractures

(a) Fissure fractures

(b) Composite fractures

(2) Lateral fractures

(a) Fissure fractures

(b) Composite fractures

(3) Anterior fractures

(a) Fissure fractures

(b) Composite fractures

*B. Fractures of the vault*

(1) Fissure fractures

(2) Composite fractures

(3) Depressed fractures

3. Five hundred and seven cases occurred in children and adults whose ages ranged from the first decade of life to the tenth decade. In this group, the complications which caused death were considered in detail.

*Deaths Caused by Acute Suppurative Meningitis and Other Septic Infections Caused by the Fracture of the Skull.*—In the series of 507 cases, forty-eight patients died of acute suppurative leptomeningitis or some type of general septic infection. In every case the source of the fatal infection was obviously the fracture of the skull. A tabulation of the age, casualty and duration of clinical course brought out many interesting points.

**Meningitis:** The table of casualties did not give any significant information. The age categories showed, however, that, while the adult decades were well represented, the proportion of children below 10 years of age was rather large. The clinical course was invariably of several days' duration, and not infrequently the patient lingered for several weeks.

The meningitis could be traced either to one of the bony sinuses of the skull or to infection which entered by means of a compound fracture. The probable source of the infection was tabulated in connection with the variety of the fracture.

Seven posterior fractures caused meningitis, and in every case they sent a branch into the mastoid and middle ear areas, in which the infection originated. Six of these bony sinuses showed a frank purulent exudate.

There were seventeen lateral fractures, and in every case the fracture involved the sphenoidal sinus or the middle ear region, as the table indicated. A purulent exudate was found in the middle ear cavities in four cases, blood was found in three cases but not any mention was made of the contents in nine cases. Two of the sphenoidal bony cavities contained a purulent exudate. Its presence apparently was not necessary for the development of the meningitis.

Five of the lateral composite fractures were caused by the crushing effect of an automobile wheel and anatomically were similar in all respects to the same fractures that have been described as having caused death by concussion. In these cases, apparently, the injury did not produce enough shock to cause an immediately fatal result, but the breaking of the bony sinuses eventually allowed infection to reach the meninges.

In one case of a lateral linear fracture, the ear drum was ruptured, and infection entered the middle ear cavity from the outside. In the course of time, the roof of the middle ear was eroded by the septic process, and a typical brain abscess developed in the substance of the adjacent temporal lobe by direct extension. The suppurative leptomeningitis that finally caused death was secondary to the brain abscess.

A comparatively large proportion of fractures occurred in the anterior part of the skull—seventeen. In fifteen cases, the meningitis developed from fractures which involved the frontal cavities, the eth-



4. Death in 139 cases was caused by cerebral concussion. The majority of these patients died in the first hour following the trauma, and all succumbed inside of the tenth hour. The fractures were, for the most part, severe and extensive.

5. Death from exhaustion occurred in fourteen instances. The injured persons did not die immediately, but they were unable to rally against the primary shock, finally dying after periods varying from one to twenty days. In one case, extensive contusions in the motor area of the right cerebral cortex induced violent convulsions which finally brought about death from exhaustion.

6. Death in twenty-seven cases was caused by a terminal lobular pneumonia, which as a rule set in from two to nine days after the injury.

7. A large number of patients succumbed to cerebral compression, caused by subdural hemorrhage in 132 instances, and to extensive lacerations of the brain in twenty-four instances.

(a) The majority of subdural hemorrhages were the result of contre-coup or direct lacerations of the cerebral cortex. A few were produced by the tearing of tributary veins from the brain to the superior longitudinal sinus, and one was caused by the tearing of an old adhesion between the brain and the dura. In one case, laceration of the dura and a branch of the middle meningeal artery caused the artery to bleed profusely into the right subdural space.

(b) The fatal lacerations of the brain were either surface lesions which covered a wide area of the cerebral cortex or big cavities in the brain substance which contained a large quantity of blood. Some of these caused extensive hemorrhages in the ventricles of the brain. None of the lesions, however, were accompanied by a subdural hemorrhage of any size.

There was reason to believe that many of the cases in this group showed a moderate grade of edema of the brain.

8. Sixty-one patients died of cerebral compression caused by an epidural hemorrhage. Most of the hemorrhages were the result of a laceration of the middle meningeal artery by the fractured bone. The posterior branches of the middle meningeal were involved much more frequently than the anterior branches. A few hemorrhages were caused by lacerations of the lateral sinus. One hemorrhage arose from a laceration of one of the anterior meningeal arteries.

9. The interval between the casualty and the death varied considerably in the cases of cerebral compression. Most persons succumbed during the first twenty-four hours, but others lingered for from eight to fourteen days.

10. Acute suppurative leptomeningitis was responsible for the death of the patients in forty-one cases. Fractures across the bony sinuses

moldal cells or other adjacent bony sinus. A purulent exudate was present in the frontal sinus in one instance, and several times a little extravasated blood was found. The frontal bony sinus was fractured in four cases, not only across its roof, but also in the anterior portion, and a laceration of the forehead made the fracture compound. However, the meningitis developed just as readily in the absence of purulent foci or

TABLE 15.—Cases of Meningitis and General Sepsis

Age Incidence									
Years	Meningitis	General Sepsis	Years	Meningitis	General Sepsis				
1 to 10.....	11	..	40 to 50.....	7	1				
10 to 20.....	2	..	50 to 60.....	2	2				
20 to 30.....	9	3	60 to 70.....	0	..				
30 to 40.....	9	1	70 to 80.....	1	..				
Total.....				41	7				
Casualty Incidence									
Automobile accidents.....	13	2	Struck by falling brick.....	1	..				
Street car accidents.....	1	..	Horse kick.....	1	..				
High falls.....	5	..	Knocked down in assault.....	1	..				
Low falls.....	6	2	Blunt instruments.....	2	3				
Falls down stairs.....	3	..	Cause unknown.....	8	..				
Total.....				41	7				
Duration of Clinical Course									
2 days.....	2	..	8 to 11 days.....	8	2				
3 days.....	6	..	12 to 20 days.....	2	1				
4 days.....	3	..	20 to 30 days.....	4	1				
5 days.....	4	..	Over 30 days.....	1	..				
6 days.....	5	3	Unknown.....	4	..				
7 days.....	2	..							
Total.....				41	7				
Source of Infection in the Meningitis Cases									
Types of Fractures									
Source of Infection	Posterior Fis-sure	Posterior Com-posite	Lat-eral Fis-sure	Lat-eral Com-posite	Lateral Com-posite Crush	Anterior Fis-sure	Anterior Com-posite		
Middle ear and mas-toid	6	1	5	3	3	..	..	18	Pus present in sinus 10
Sphenoidal sinus.....	..	..	..	1	2	..	..	3	Pus present in sinus 2
Middle ear and sphenoid combined	..	..	..	2	..	..	..	2	
External ear.....	..	..	1	..	..	..	..	1	Abscess temporal area, 1
Sinuses in frontal area	..	..	..	..	..	6	9	15	Pus present in frontal sinus, 1
Compound fracture.	..	..	..	..	..	..	2	2	Abscess frontal area, 1
	6	1	6	6	5	6	11	41	

compound fractures, probably because the cavities in the frontal region had free communication with the outside through the nose.

In two cases the probable entrance of the infection was through a compound composite fracture of the frontal bones above the eyebrow region, in which an extensive laceration freely exposed the shattered skull. One of these persons lived for six weeks and developed a brain abscess in the frontal lobe just over a small direct laceration of the brain adjacent to the fracture. The abscess eventually eroded into the

of the skull caused the infection in the majority of instances, although in two cases the organism entered through a compound fracture.

11. Seven persons died of various other septic infections caused by the fracture of the skull. The infective agent gained entrance through compound fractures and through fractures involving a bony sinus. Two of the patients developed a typical *Staphylococcus aureus* septicemia with thrombosis of the lateral sinus and septic infarcts in the lungs. One person died of a general septicemia caused by the hemolytic streptococcus. Other patients developed large collections of pus in the epidural and subdural spaces.

12. Patients who died of suppurative meningitis or other form of sepsis lingered for from several days to several weeks. The infections were insidious in their onset and, once established, were inevitably fatal.

13. Four patients died as the result of an operation on the skull. One woman died under ether anesthesia. Two patients died as the result of postoperative shock. One man died during the progress of the craniotomy, death being caused by a profuse hemorrhage from the superior longitudinal sinus, which had been lacerated by the fracture.

14. Three persons died as the result of a traumatic epilepsy, which was associated with an old extensive adhesion of the brain to the dura, mainly in the frontal region. The convulsions usually set in several months after the primary symptoms of the fracture had subsided, and the patients survived from one and one-half to two years after the injury.

15. Thirty patients died as the result of injuries in other parts of the body which were caused by the same violence that fractured the skull.

16. Twenty-five patients died as the result of a condition which did not have any connection with the trauma.

17. Five of the 512 patients who came to necropsy were new-born infants or infants under 5 months. The skull at this age is not a homogeneous bony case, but it is composed of bony plates held together by tough membrane. This peculiarity served to confine the fracture to the bones primarily struck, which in most cases were the parietal. The cause of death was usually concussion or exhaustion, although one baby developed a subdural hemorrhage from a direct laceration of the brain.

## PART II. CLINICAL ASPECT OF COMPLICATIONS PRODUCED BY FRACTURES OF THE SKULL<sup>4</sup>

The clinical records are from the wards of the first surgical division of Bellevue Hospital, and cover a period of five years, from 1919 to 1924. Sixty-one cases are presented in detail. These comprise cases of

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4. Many of the fatal cases in this series were included in the necropsy material in part I, but, as the two series were considered separately, there was no duplication.

lateral ventricle, causing a general spread of the purulent material through the cavities of the brain.

The manner in which the infection spread from the different foci to the subarachnoid space was not always obvious, and in most instances the anatomic features of the meningitis did not give any information on this point. All varieties of the lesion were described; generally purulent exudate was found involving the region of the base around the circle of Willis, or else spread in various ways over the vertex of the cerebral hemisphere. In three cases the purulent exudate was heavy and thick in the cistern around the foramen of Magendie, and a severe purulent hydrocephalus was the result. The ventricles of the brain were filled with turbid cerebrospinal fluid, and the distention caused a severe degree of intracranial tension.

In a few instances, especially around slight cerebral lacerations, a purulent membrane of varying extent was found adherent to the inside of the dura—a true suppurative pachymeningitis. The infecting organism had in some way reached the dura as well as the arachnoid, probably aided by the presence of small hemorrhage on the inside and outside of the dura, which formed an excellent culture medium for the bacteria.

Bacteriologic examinations of the meningeal exudate were made only in a few instances, but in every successful culture the bacterium was invariably the pneumococcus.

In all the cases which have been considered, the meningitis was the result of fracture of the skull. Sometimes, however, the question arose whether the presence of the infection was caused by the injury or was merely a coincidence.<sup>3</sup> This point was to be determined only by the clinical history. The fracture could be responsible for the meningitis only if it preceded the onset of the infection by two days or more, and was of the type that permitted the bacteria to invade the skull.

The general impression given was that the condition was insidious. The trauma was at times severe, and the diagnosis of fracture of the skull was never in doubt. Often, however, a slight injury would crack the thin bony plates which roofed the cavities at the base, and this was sufficient to allow bacteria to gain entrance. The primary effects of the violence were sometimes negligible, and it was difficult to be sure that a skull fracture was present. Accordingly, in many instances the meningitis was apparent after a lapse of several days, almost without warning, and brought about an inevitably fatal outcome.

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3. Since this paper was written, a man, aged 60, came to necropsy with a history that he had fallen down a sewer and had died a few hours after the fall. Postmortem examination disclosed a small fracture in the frontal region and a marked suppurative meningitis of several days' duration. It was probable that the fall was due to giddiness resulting from the meningitis, and that the fracture had nothing to do with the infection of the meninges, which was a spontaneous infection.

fatal fractures of the skull in which a craniotomy had been performed, and cases of fractures from which the patient recovered both after operation and under expectant treatment. All that survived were placed under observation after leaving the hospital, either until the patient was considered to have recovered from the effects of the injury or until he could no longer be found by the "follow-up".

A number of cases in which craniotomy was not performed and the patients died are not included, as the clinical histories in all such cases were similar and can be discussed adequately in a few words.

For the sake of convenience, an arbitrary division of the clinical material is made as follows: (A) fatal cases in which craniotomy was not performed. (B) operative cases, fatal and nonfatal. (C) fractures of the skull from which the patients recovered under expectant treatment.

#### FATAL CASES IN WHICH CRANIOTOMY WAS NOT PERFORMED

Fractures of the skull from patients who died without having an operation performed were of two varieties.

The patients who had the first type were admitted in a moribund condition, suffering from profound cerebral concussion caused by a recent trauma; or they had been injured several hours or days before they reached the hospital and were in the last stages of cerebral compression or meningitis. The clinical signs often did not give any indication of the nature of the intracranial condition. The patients were in a state of profound prostration, shown mostly by deep coma, complete insensibility, flaccidity of all muscles, stertorous respiration, pupils fixed and not responsive to light and a pulse and temperature variable in reaction. The poor physical condition of the patient was a clear contraindication against a craniotomy; in addition, there was not anything to suggest that the operation would have been of any avail.

The patients who had the second type were admitted to the hospital showing few signs of injury and often perfectly conscious and rational. They usually lived for several days, and during their stay in the ward did not develop any signs or symptoms which encouraged the surgeon to operate. They finally lapsed into coma and died. At necropsy, death was found to be due to causes of such insidious onset as an acute suppurative meningitis, general septic infection or terminal bronchopneumonia.

#### OPERATIVE CASES

In deciding on the advisability of operation, the clinician must answer two questions. 1. Do the clinical observations indicate a fracture of the skull? 2. Are the signs definite enough to identify an intracranial condition which will be benefited by craniotomy?

**Other Septic Infections:** The cases of septic infections were seven in number and were also characterized by delayed onset of symptoms, but when the condition was established, death was inevitable. The clinical course varied from six to twenty-four days.

In the four following instances the infection entered through a compound fracture of the vault, three of which were caused by assaults with blunt instruments, while one developed from a fall against an iron rail.

A white man, aged 39 years, received a compound depressed fracture of the parietal region of the vault when he was struck by the corner of a revolver butt. After a nine days' course, the case came to necropsy, disclosing a large decompression window in which the fracture had been present, an infected hernia cerebri protruding through this opening and signs of general septicemia, including a suppurative meningitis and an acute vegetative endocarditis of the mitral and tricuspid valves. A hemolytic streptococcus was isolated from the meningeal pus and from the splenic pulp.

Another patient, a colored man, aged 29 years, who had received a small compound depressed fracture in the left frontal region, lived six days. He died during the course of a decompression operation performed shortly after his admission to a hospital. Necropsy disclosed the fracture and the way in which the bacteria gained entrance through the hole in the scalp and skull. Just beneath the broken bone the dura was intact, but there was a small extradural collection of purulent fibrin in this area. In addition, there were signs of general septicemia, which comprised an extensive purulent pachymeningitis and leptomeningitis and hemorrhagic nephritis. A bacteriologic examination was not made in this case.

One case of *Staphylococcus aureus* septicemia was described, following a compound depressed fracture in the left parietal region. A craniotomy was performed, and the patient survived only thirteen days. Necropsy showed an infected scalp wound and infected dura near the decompression site, with extension of septic thrombi through the smaller vessels of the dura to the right lateral sinus. The lungs were filled with huge embolic abscesses and septic infarcts. The picture was typical of staphylococcus infections, and the organism was cultivated from the abscesses of the spleen and of the lung.

In the fourth case there was a compound comminuted fracture in the right parietal region on which an operation was not performed. The patient lived for nine days. At necropsy, there was a collection of purulent fibrin which accompanied the middle meningeal vessels on the right side in a dentritic pattern to the foramen spinosum. There was no infection of the inside of the dura or brain, but there were signs of general septicemia, such as abscesses of the kidney and abscesses in the left psoas muscle and left elbow. The body was embalmed, and it was not possible to make a bacteriologic examination.

The other cases were the result of a fall in one instance and of automobile injuries in the other two. The fractures were not compound, but involved the middle ear region, and it was from this bony sinus that the septic infection originated.

One man fell from a ladder and sustained a posterior linear fracture which extended into the right mastoid cavities. After twenty-four days he died as the result of a septic thrombosis of the right lateral sinus, with multiple septic infarcts in the lungs.

*Diagnosis of the Fracture.*—The presence of a fracture of the skull was determined in several ways—by the history of the trauma, by the general condition of the patient, by the external signs of the injury of the head, by examination of the spinal fluid and finally by roentgen-ray examination of the skull.

(a) History of the Trauma: Information concerning any injury which the patient might have received always helped in making a diagnosis. In the majority of cases this information was available, although a few persons were admitted to the hospital in an unconscious state without any previous history. The chief value of this information lay in the fact that it gave the clinician a suggestion of what investigations he should pursue.

(b) General Condition of the Patient: If there were definite signs of well marked cerebral concussion or cerebral compression, the suggestion that the patient was suffering from some intracranial injury and perhaps from a fracture of the skull could be entertained with reasonable certainty.

As has been noted, concussion occurred immediately after the trauma, and the patient appeared in a state of prostration and coma which lasted for a variable period of time. Sometimes it was of long duration, and the patient was unconscious for days; in other cases, it passed away within the hour, and the patient recovered his faculties completely. In rare instances, the fracture occurred without any signs of concussion. Generally, on admission to the hospital, the patient presented cerebral symptoms of moderate severity and was described as stuporous or easily aroused, irrational, mentally confused and irritable, often complaining of vertigo, headache and vomiting.

Cerebral compression was often present on admission, but it was not always easy to recognize it as such until many clinical tests had been tried, especially when deep coma had already begun. The most typical instances occurred in patients who were admitted to the hospital in a rational condition and then lapsed gradually into unconsciousness, complaining of increasingly severe headache, vertigo and vomiting, with slowing of the pulse rate and a rise of blood pressure. Unfortunately, the patient was not always observed at this characteristic stage, and then the symptomatology gave little assistance. Reliance had to be placed on a study of various signs, which included the pulse and blood pressure records, the pressure of the spinal fluid, examination of the eyegrounds and a consideration of the various neurologic signs.

The pulse and blood pressure readings, while important, had to be interpreted with some degree of caution. So many factors influenced the circulatory system that neither the pulse nor the blood pressure reacted to intracranial conditions with any degree of consistency.

The two automobile accidents caused lateral fractures which shattered the middle ear region. One man developed a huge foul abscess between the dura and the skull of the middle fossa, with marked necrosis of the mastoid area, but abscesses were not found elsewhere. In the other case in which there was a similar but less extensive fracture, a marked suppurative pachymeningitis interna was seen near the region of the fracture, but leptomeningitis or any other anatomic signs of infection were not present. Both these persons lived about six days.

The essential factor in all these cases was that the fracture permitted the entrance of the microorganism through the skull, and that conditions were such that its spread was further facilitated. Any small intracranial extravasations of blood, especially small epidural clots under a compound fracture, made a splendid nidus in which pathogenic bacteria could grow, and when they reached such a lesion, the invasion was established definitely.

TABLE 16.—*Deaths Caused by Operative Procedures*

Age, Color, Sex	Casualty	Fracture	Procedure	Cause of Death
White woman 46 years	Low fall	Anterior linear fracture	Given ether anesthetic for a Colles fracture of left wrist	Ether anesthetic; died during anesthetic
White boy 14 years	Automobile	Posterior linear fracture; direct and contre-coup brain laceration	Bilateral decompression for intracranial pressure; operated on day of injury	Postoperative shock; died a few hours after operation
White man 63 years	Automobile	Composite vault fracture; direct and contre-coup laceration; fracture of ribs and left clavicle	Decompression in area of comminuted fracture; operated on day of injury	Postoperative shock; died a few hours after operation
White man 21 years	Automobile	Compound lateral fracture with tear of superior longitudinal venous sinus	Decompression to stop hemorrhage from venous sinus; operated on day of injury	Sudden death from hemorrhage during operation

*Deaths Caused by Operative Procedures: Postoperative Shock.*—

This group included four cases; three of the patients died because of the operation on the skull, while one died under ether anesthesia. The data are given in table 16.

The first three cases do not require detailed comment.

The fourth, however, was the only example in the series of an epidural hemorrhage which resulted from laceration of the superior longitudinal sinus. The fracture as first noted during life was a compound depressed fracture on the right of the midline over the coronal suture. During the removal of the bony fragments at operation, it was discovered that the superior longitudinal venous sinus was torn by the sharp edges of the fracture, and that one of the tributary veins on the inside of the dura was similarly torn. These bleeding points were rapidly sutured, but the patient lost so much blood during the procedure



In a typical case of cerebral compression the pulse became slow, dropping from a rate of from 70 to 90 a minute to about 40 to 60 a minute. It was then described as a slow and bounding, or as a "high tension," pulse. Occasionally it was rapid and weak, and its rate was as high as 120 a minute. Its value as a diagnostic sign was, on the whole, rather limited.

The blood pressure readings also varied. A high blood pressure of systolic 180 and diastolic 80 or one of systolic 230 and diastolic 90 indicated definitely a severe grade of intracranial pressure.

However, many patients showed comparatively low pressures, such as systolic 128 and diastolic 80, and the like. It was not infrequent to find a great variation in the blood pressure records in the same patient when they were taken at different times. The observations were not consistent enough nor were the readings taken frequently enough to allow definite conclusions to be formulated; but apparently during the first few hours of the clinical course, the systolic blood pressure was high, and in the later stages it tended to drop as much as 40 or 60 points. This suggested that the circulation either was adapting itself to an abnormal condition or was weakening under the strain. It also indicated that the readings had to be taken at frequent intervals in order to convey information of significance.

In some instances, the spinal fluid was blood-stained and flowed out under pressure. This was a reliable sign of intracranial tension, but the phenomenon was recorded only as a qualitative observation. A manometer was not available at the time the patients in this series were in the wards, so quantitative measurements of spinal fluid pressure were not made. There was, therefore, no criterion by which to compare the degree of pressure in the different patients.

Ophthalmoscopic examination of the eyegrounds revealed circulatory disturbances in that region and so gave valuable information concerning intracranial pressure. In cases of moderate severity, the vessels of the disk were engorged, the disk appeared hazy or in some cases definite papilledema was found. In several instances, the ophthalmoscopic examination showed that the eyegrounds were affected more on one side than on the other, and generally the cause of the increased pressure was located on the side of the more involved eyeground.

The neurologic examination was always necessary in any case of injury of the head, especially if a craniotomy was under consideration, for it often located the point of disturbance with a fair degree of accuracy. These tests included a routine determination of the following points: (1) conditions of the pupils and the oculomotor system; (2) conditions of the facial and tongue muscles; (3) superficial reflexes of the trunk; (4) deep reflexes of the extremities; (5) abnormal neurologic reactions, such as patellar and ankle clonus, Babinski and Kernig sign.

that he died on the table. At necropsy, the decompression window was found in the region already noted, with a linear fracture on its left extending down the coronal suture to the left middle fossa, while another linear fracture on its right ran diagonally in a posterior direction to the right posterior fossa. The fracture had been produced by severe violence, for on the vault the posterior edges of the fracture were displaced to the left of the anterior edges. The sinus and its tributaries had been sutured, but the general pallor of the body indicated that much blood had been lost. The brain showed a laceration at the site of the decompression, about  $1\frac{1}{2}$  by 2 inches, and there was a hernia cerebri present in the opening through the skull. Contre-coup lacerations of the brain were not found.

In the series of 507 cases, thirty additional trephine operations were performed, but, while they did not help the patient materially, there was not any evidence to indicate that they were responsible for the fatal termination. Thirteen were tried in cases included in the subdural hemorrhage and lacerated brain categories, seven in epidural hemorrhages, four in cases of meningitis, four in cases of general septic infection and two on patients who died of pneumonia. Relatively little information, however, was furnished by these unsuccessful operations, and the advisability of the procedure was best considered among the cases studied clinically.

*Deaths from Epileptic Convulsions.*—Death from epileptic convulsions was diagnosed in three cases. The patients had received a fracture of the skull a year and a half to two years prior to death and had recovered from the immediate effects of the injury. Two of the fractures were compound composite fractures in the frontal region of the vault, which had caused an extensive direct laceration of the adjacent frontal lobe of the brain. An operation had been performed, and at necropsy the brain was found firmly adherent to the decompression window by a pigmented scar. The third case showed an old healed depressed fracture in the left posterior parietal region, while the lateral frontal region on the right was extensively adherent to the dura over a wide area by pigmented scar tissues, which was obviously the result of an old contre-coup laceration in this region.

The data are given in table 17.

In each case there was a latent period of several months after the immediate effects of the injury were entirely over, and the patient was discharged as cured. Then convulsions began and grew worse until death ensued. The adhesions obviously had some association with the convulsions, but the nature of their influence was not evident. The etiology of this type of epilepsy was just as obscure as that of idiopathic epilepsy.

stiff neck and others; (6) abnormal conditions of muscular groups, such as weaknesses, spastic and flaccid paralysis and convulsive seizures.

1. The reaction of the pupil to light was determined, it being especially noted whether the reflex was absent or sluggish. If the patient was at all rational, the test for accommodation was tried. The information so obtained was generally inconclusive, except that a sluggish or immobile pupil indicated that the intracranial complications were probably severe.

In several instances the pupils were unequal, one was dilated, while the other was contracted, and this sign seemed to point to a lesion definitely located on one side of the cranial cavity. In seven fatal cases in which there was a subsequent necropsy, the right pupil was observed to be much larger than the left. Five of these showed an epidural hemorrhage on the right, one a subdural hemorrhage on the right and one an epidural hemorrhage on the left. The cause of the inequality was not easy to determine, but the difference in the size of the pupils depended, apparently, on the unilateral nature of the intracranial condition.

Abnormalities of the oculomotor muscles, such as deviation of the eyes to the right and the head to the left and lateral movements of the eyeballs or nystagmus, were also noted. This, in all probability, was caused by cortical irritation, but the explanation was not obvious.

2. Paralysis and weakness of the facial muscles on one side and deviation of the tongue to one side were noted, but, beyond indicating some sort of intracranial disturbance, their significance was uncertain. Many of these phenomena were transitory and cleared up finally.

3. The superficial reflexes of the trunk, namely, the abdominal and cremasteric reflexes, were occasionally active and equal, sometimes absent on both sides, and at other times more active on one side than on the other. These reflexes apparently became less and less active as the intracranial condition increased in severity, and thus varied with the condition of the patient, but their value as a guide to cerebral involvement was limited.

4. The various deep reflexes, including the biceps, triceps, patellar and Achilles' tendon reflexes, also varied, from being equal and hyperactive or equal and sluggish to being markedly unequal, when one side was much more active than the other. This generally indicated a unilateral intracranial lesion, but did not always indicate the side of the brain involved nor the nature of the lesion causing the trouble. The presumption was that the cerebral cortex was affected in some way.

5. The abnormal reflexes, such as patellar clonus, Babinski's reaction and several others, also indicated cortical involvement of some kind, generally of considerable severity. Much significance was attached to these abnormal reflexes when they were more pronounced on one side than on the other, and the inference was that the side which reacted

was sarcoma. While at the Memorial Hospital the patient was treated with massive doses of radium (60,804 millicurie hours at 7 cm. distance) and the mixed toxins; the latter were injected systemically in the buttocks. He received eleven doses while in the hospital, and further injections were given at home.

The patient was well when last heard from, February, 1926, six years later.

CASE 24.—*Periosteal osteogenic sarcoma of tibia.* J. C., a boy, aged 15 years, in the latter part of July, 1921, while playing was struck with a baseball on the



Fig. 49 (case 108 in table 7).—Inoperable sarcoma of first rib (clinical and roentgen-ray diagnosis).

inner aspect of the right tibia. Shortly after, a small lump appeared at the site of the injury and steadily increased in size; pain soon followed, and the patient walked with great difficulty. Wet dressings were at first applied, and later plaster strappings. Four electric treatments were given by Dr. Sidney Twinch of Newark, N. J., who had a roentgenogram taken and pronounced the trouble sarcoma. The patient was then referred to us for treatment. He was admitted to the Hospital for Ruptured and Crippled in the early part of October, 1921.

Physical examination at this time showed enlargement of the upper half of the right tibia, apparently of bony origin, extending up to but apparently not involving

the joint. There was slight restriction of motion at the joint but no effusion. The clinical diagnosis was periosteal sarcoma apparently of traumatic origin.

October 5, we performed an exploratory operation: a 3-inch (7.6 cm.) incision was made over the anterior portion of the right tibia just below the knee joint; the periosteum was found to be markedly thickened and intimately connected with the neoplasm, which apparently involved the greater portion of the cancellous tissue of the bone. The patient was immediately started on systemic injections of the mixed toxins of erysipelas and *Bacillus prodigiosus*. He was sent to the Memorial Hospital, October 21, where he received radium treatment in the form of a pack over various areas at 6 cm. distance, totaling 40,162 millicurie hours. Some definite decrease in the size of the tumor was noticed after the treatment. A

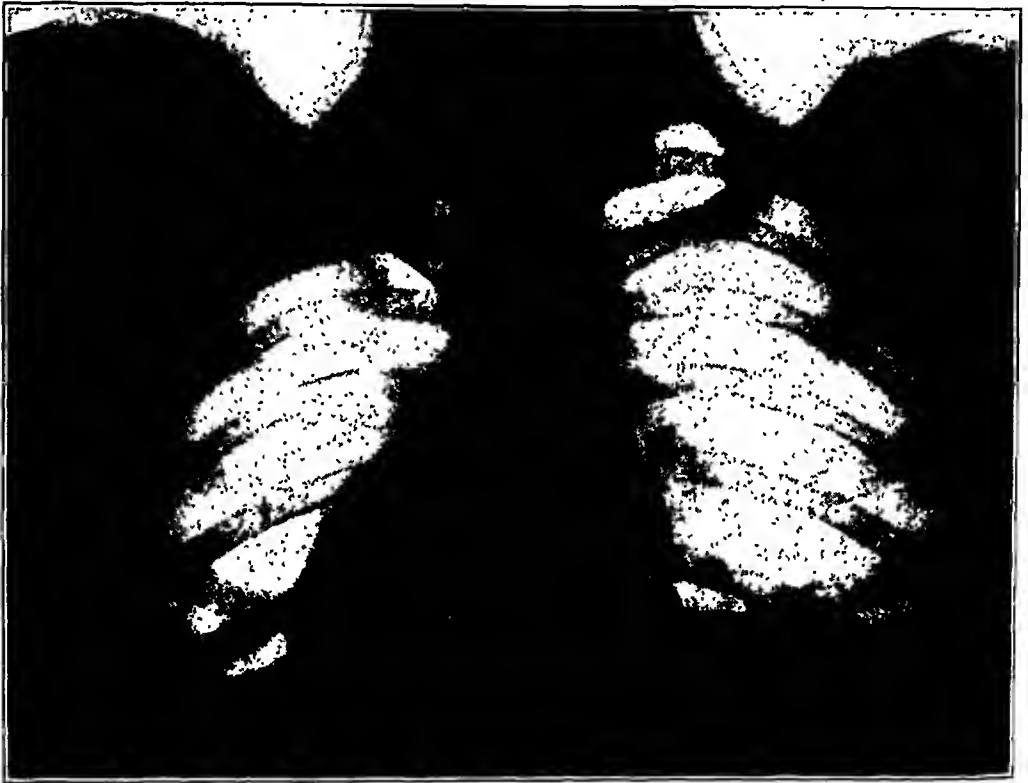


Fig. 50 (case 108 in table 7).—Eight years later; recovery under toxins and radium treatment.

roentgenogram taken in November showed the right tibia occupied by a periosteal osteogenic sarcoma involving the entire upper half, and apparently extending into the joint as well. There was some evidence of marked new bone production. This picture, when compared with one taken in October, showed some decrease in the size of the tumor. The toxins were kept up until twenty-eight injections had been given. The improvement, however, proved only temporary, and Dec. 2, 1925, an amputation at the midfemur was performed by one of us (B. L. C.); the wound healed by primary union. Following the amputation, the toxins were immediately resumed as a prophylactic, and continued at home for about six months by the local physician. A microscopic examination was made by Dr. F. M. Jeffries, who reported osteosarcoma: Dr. James Ewing's microscopic diagnosis was perios-

the strongest referred its behavior to the corresponding motor area of the cerebral cortex, which had been injured.

The occurrence of an abnormally rigid neck and a positive Kernig sign was generally referable to a suppurative leptomeningitis, but was also caused by subarachnoid hemorrhages, which could also produce cortical irritation. The only way in which differentiation could be made with any degree of certainty was by examination of the spinal fluid.

6. The presence of weakness, paralysis or convulsions in various muscle groups, however, was a sign of great importance, and will be discussed at greater length later. The lesions giving rise to these abnormalities were various and could be located fairly definitely over some portion of the brain. As a rule they indicated involvement of certain areas of the motor cortex, always on the side of the brain opposite to the paralyzed muscles. In some instances the lesion was a direct laceration of the motor area, in others it was a depressed fracture impinging on the cortex and in many it was an epidural or subdural hemorrhage pressing in the brain substance. The definite nature of the clinical sign usually suggested the site where a craniotomy would be most likely to relieve the intracranial complication.

(c) Signs of External Injury: The external signs of injury of the head were always important, because through them the fracture could be located with a reasonable degree of certainty in a large number of cases. At least, they indicated where violence had been applied to the head and so suggested what intracranial conditions might logically follow the trauma. Injuries of the scalp were important in this respect.

The scalp was particularly vulnerable to the violence, as it consisted of a layer of skin applied closely to the underlying hard cranium. Impact against a projection caused lacerations of varying length and depth, which were linear or stellate if the force was applied at right angles to the skin, but which resulted in a flap of skin if the projection impinged on the scalp tangentially. Occasionally a fracture of the skull was seen at the bottom of the laceration.

If the head came in contact with a smooth surface, the scalp injury was not always obvious. Direct impact, however, at times produced a contusion of the superficial layers without laceration. Sometimes a lesion of this kind appeared as a mound with a softened area in the center, where the force had turned the fat into pulp. A tangential impact produced abrasions of different degrees, sometimes associated with a contusion. In a few cases, the violence did not produce skin lesions of any kind; generally the force was a relatively slight one, and the skull was thin.

In some instances, a local lesion was not evident on the surface of the skin but a huge, doughy hematoma of the vault was often present, causing the scalp to bulge perceptibly in certain regions. Investigation

The third case (case 10), showed bleeding from the right ear, signs of intracranial pressure, according to the blood pressure and pulse, and the deep reflexes on the left were greater than those on the right. A right subtemporal craniotomy was performed a few hours after admission, and blood and brain tissue were evacuated from the epidural and subdural spaces. The lesion was probably a laceration of the brain on the side of the fracture complicated by a subdural hemorrhage.

These cases contrasted rather sharply with the fatal ones, in which the general condition of the patient on admission, with a few exceptions, was described as serious, the degree of intracranial pressure was often much more marked, and the neurologic signs were usually more pronounced. The histories indicated that, on the whole, the intensity of the intracranial complication was much less in the patients that recovered. It was also obvious that the craniotomy was clearly indicated in all three instances, for without it death would have been inevitable.

#### OPERATION FOR COMPOUND FRACTURE RECOVERY

CASE 1.—I. B., a white man, aged 26, was struck by an automobile. He was conscious on admission to the hospital. A compound fracture was found in the anterior portion of the left parietal region. The left reflexes were hyperactive. Craniotomy was performed on the day of admission. The external wound was excised, and the bone was removed by rongeur forceps. The dura was intact and was not opened, but a needle was inserted, and clear cerebrospinal fluid was obtained. The length of the stay in the hospital was twenty-five days.

One year later the patient had a slight palpable pulsation at the site of the craniotomy; the left pupil was slightly larger than the right, and he showed a slight Romberg sign.

CASE 2.—J. T., a white man, aged 28, fell down a hatchway. He was conscious and rational on admission. A compound fracture involving the frontal sinus was found on the forehead. Craniotomy was performed eight days later. Recovery was uneventful; the patient was in the hospital ten days.

When this patient was seen later, a bony deformity was present at the operative site, but the patient did not have any other symptoms.

CASE 3.—J. McK., a white man, aged 55, was struck on the head by a cuspidor. On admission, he was alcoholic and stuporous, but he was easily aroused. In the left parietal region, a comminuted compound fracture containing hair was found. The patient showed a pure motor aphasia, that is, he could understand, but could not speak distinctly. Craniotomy was performed on the day of admission. After a right angle incision exposing the wound, bone fragments were removed by rongeur forceps, and a bleeding branch of the middle meningeal artery was ligated. The epidural clot was removed. A rent 2 cm. in length was found in the dura and closed. On discharge, twenty-eight days later, the patient was still a little aphasic, as he had difficulty in speaking, although he could read and write. He was also slightly dizzy. There was a sinus in the field of operation which still discharged.

Three months later, he complained of dizziness and was unable to pronounce words well. The sinus in the wound still discharged fluid. He did not report subsequently.

showed that much extravasated blood was present in the galea or was separating the galea from the skull. The hemorrhage was often caused by an extensive fracture which admitted blood through the broken bone from the inside of the cranium. In cases in which the dura and brain were lacerated, traumatized brain tissue was often found with the blood. In two cases, hematomas of this kind were observed to increase in size while the patient was in the ward, and thus served to establish the site of the fracture with a reasonable degree of certainty.

In some instances in the necropsy material, fractures resulting from the crushing action of an automobile wheel were sometimes accompanied by separation of the scalp from the bone, without an external tear of the skin. The grinding action of the wheel caused the separation and produced a hematoma from the torn vessels near the junction of the scalp and the skull. This lesion was found mainly on the lateral part of the head. In several instances, however, the scalp was torn rather extensively by the violence, especially in the region of the ear.

Among the sixty-one cases, injuries of the scalp occurred as follows: lacerations with compound fractures, 12; lacerations, 18; contusions and hematomas, 16; abrasions, 3; no scalp injuries, 12.

Five of the twelve cases of uninjured scalps did not show demonstrable external trauma of any kind. This point was observed many times in the necropsy material and indicated that a serious fracture of the skull was not necessarily accompanied by surface injuries.

Other signs of external injury were hematomas of the eyelids, bleeding from the nose, mouth and ears and vomiting of blood from the stomach.

The hematomas of the eyelids were of different degrees, varying from a contusion of small size to huge swellings in both lids, sufficient to close them. They involved either one side or both and also were confined to either the lower or the upper lid, or they involved both. In many cases the ecchymosis was caused by rupture of one of the superficial blood vessels in the loose lid tissue and was not associated with fracture of the skull. In other instances, there was a fracture of the orbital plate, and the hemorrhage arose from rupture of a vessel inside the orbit, which bled through the fracture. The orbital lesion was generally the result of violence applied to the frontal region, but occasionally occurred as the result of a severe trauma applied to another portion of the skull.

In the series of sixty-one cases, hematomas of the eyelids occurred five times on the right side, six times on the left and once on both sides. As a rule, this sign merely indicated some kind of an injury and did little more than suggest the presence of a fracture.

In one instance there was a condition of subcutaneous emphysema in the frontal region, associated with ecchymosis in the eyelids. This was



CASE 4.—L. D., a white man, aged 30, fell two stories to a sidewalk while cleaning windows. When admitted to the hospital he was unconscious. A compound fracture was present in the right parietal region and a hematoma of the left vault. On the second day, a craniotomy was performed in the right parietal region; a broken bone was removed, but the dura was left intact. The patient became semicomatose and had a slow pulse rate. The hematoma of the left vault increased in size. On the third day, a second craniotomy was performed over the left temporal region. A stellate fissure fracture was found with fresh blood oozing through the fracture line. A large area of bone was removed by rongeur forceps, and an epidural clot was removed. The dura was incised, and from 20 to 30 cc. of blood was evacuated. Recovery was slow. The patient was discharged at the end of forty days with injuries healed.

Six months later, the patient complained of headache and stuffiness in the ears. Mentally, he was slow and irritable. The skull defects did not bulge.

CASE 5.—W. McL., a white boy, aged 14, fell two stories. He was conscious on admission to the hospital, but irrational and irritable. A compound fracture was present in the left supra-orbital region; there was a dislocation of the left elbow and a Colles fracture of the left wrist; the neck was rigid. The spinal fluid was blood tinged; the temperature was 103.8 C. On the fifth day, a craniotomy was performed in the left supra-orbital region, and the fractured bone was removed. A torn dura was discovered and an extrusion of degenerated brain tissue, which was removed; drains were inserted in the wound. After a stormy convalescence, during which the patient had a right basal pneumonia and an infected wound at the operative site, the condition cleared up. The injuries of the left arm healed, and the patient was discharged at the end of two months and eight days, permanently blind in the left eye, except for light perception, and with a bone defect on the left side of the forehead.

Two years later, the patient returned to the hospital, and a cartilage transplant from the ribs was put in in order to correct depression at the site of the old operation. This operation was successful.

Subsequent History: When the patient was 19 years old, he accidentally fell down an elevator shaft and sustained a fracture of the skull in the right frontal region, after which he developed an acute suppurative meningitis and died. Necropsy disclosed the foregoing conditions and the old healed craniotomy in the left frontal region.

CASE 6.—F. O. P., a white boy, aged 15, was shot in the forehead. He was conscious, rational and in good physical condition on admission to the hospital. There was an operative scar on the right side of the forehead, which was almost healed. Roentgen-ray examination showed a bullet in two pieces in the outer table of the skull and a small fracture there. On the fourteenth day after admission, the bullet was removed by a craniotomy on the right side of the forehead, involving both tables. A cartilage transplant from the seventh and eighth ribs on the right side was put in in order to remedy the defect. A small fragment of bullet was left in the scalp. The patient recovered completely and was discharged after twenty-nine days.

No sequelae were found.

CASE 7.—T. S., a white man, aged 44, was hit by a falling plank. He was conscious when admitted to the hospital, but in a state of shock. A large, bulging hematoma was present in the scalp, just to the left of the median line of the vault, with a laceration in the posterior parietal region. The blood pressure was low—systolic 75, diastolic 55. Convulsive jerking of the right leg was present, and



later this extremity became weak. Roentgen-ray examination disclosed a fracture of the left parietal bone, with branches to the frontal region and to the occiput, near the leg area of the rolandic fissure. A decompression operation was performed on the fifth day in the left parietal region near the laceration. The depressed fracture was reduced by rongeur, and a cartilage graft from the ninth costal cartilage was inserted in the defect. Motion of the right leg slowly returned, although the patient walked with a slightly spastic gait. There was no defect in the skull. The patient was discharged twenty-six days after admission.

One year after operation, no untoward symptoms persisted, with the exception of a slight Romberg sign, and the right knee reflex was a little exaggerated.

#### INTRACRANIAL PRESSURE

CASE 8.—A. D., a man, aged 41, slipped and fell, striking the right side of his head. He was unconscious for one hour. He vomited about ten hours later and had a hemorrhage from the nose, mouth and right ear. Pain then developed in the right temporal region, and on account of this symptom, he entered the hospital three days later. On admission, he was conscious, and any external sign of injury could not be seen, but a definite point of tenderness was found 2 cm. above the right temperomandibular region. Roentgen-ray examination showed a linear fracture in this region. The right pupil was somewhat larger than the left, and both reacted sluggishly to light and accommodation. Blood was present in the spinal fluid, but the pressure was not increased. Three days after admission, an intravenous administration of 50 cc. of a 3 per cent sodium chloride solution was given. The pulse dropped from 77 to 54 beats a minute; the right eyeground showed dilated veins and narrowed arteries, but the disk itself was normal; there was a positive Oppenheim sign on the right, and persistent headache developed. A right temporal craniotomy was then performed, and a stellate fracture of the right temporal bone was found, one fragment being depressed. The bone was removed with rongeur. A thick epidural clot was removed with a curet, and the posterior branch of the middle meningeal was found lacerated near the bifurcation; this was ligated, and the oozing from the dura was controlled by a postage stamp graft of muscle. Recovery was uneventful. The patient was discharged at the end of twenty-eight days.

There were no sequelae.

CASE 9.—W. W., a negro, aged 27, was hit by a falling brick. He was admitted in a semicomatose condition. A compound depressed fracture was present in the left parietal region. A hematoma of the right eyelid was present. A right hemiplegia rapidly developed, except in the fingers, accompanied by a pulse rate of 92 beats a minute and a blood pressure of 110 systolic and 50 diastolic. The spinal fluid was bloody and under pressure. A left parietal craniotomy was performed on the day of admission. A depressed fracture was found, with hair and debris in the wound. The bone was removed by rongeur forceps, leaving a defect 6 by 5 cm. well beyond the soiled area. A thick layer of epidural clot was found and removed by curet. Tears of a branch of the middle meningeal artery and of the superior longitudinal sinus were found, and the bleeding points were controlled by application of aponeurotic grafts. The dura appeared normal and was not opened. There was gradual recovery of movement on the right side; the arm movements came back first; the right leg improved slowly and, even on the day of discharge, the patient had a weak ankle and a steppage gait. He was discharged twenty-four days after injury.

of the external canal, while the drum was intact and the middle ear free from blood. There was a fracture on the opposite side of the skull, but this did not have any connection with the bleeding auditory meatus. This seemed to suggest that a fracture was not always the cause of the hemorrhage. However, cases of this kind were exceptional, and in the majority of instances, bleeding from the ear canal was a reasonably certain indication of a fracture of the skull in that region.

(d) Examination of the Spinal Fluid: The spinal fluid obtained by lumbar puncture was examined in forty-seven of the sixty-one cases. Bloody fluid in all three tubes was present in thirty-nine, and, of these, fourteen recorded as under pressure. Two times the fluid was turbid, four times it had a yellowish tinge and two times it was clear. In fourteen cases there was not any record of lumbar puncture.

The bloody fluid merely indicated that there was a hemorrhage into the subarachnoid space or into the cavities of the brain from some cause, but it did not throw any light on its etiology. Both cerebral lacerations and spontaneous cerebral hemorrhages cause sanguineous lumbar punctures, so that the sign had only a limited value in differential diagnosis. Without doubt, laceration of the brain was responsible for the blood in the majority of cases considered here. The fluid often flowed out under pressure, especially during the hours immediately following the trauma.

If the patient survived a few days, the character of the fluid changed. First the color was a bright blood red, later a turbid brownish red, still later a clear brownish or yellowish color; finally, the normal clear, watery type would appear. These transformations correspond roughly to the different changes which took place in the laceration of the brain and indicated different stages in the transformation of the extravasated blood until its final disappearance.

The spinal fluid also indicated the onset of suppurative meningitis. At first, after varying intervals of several days following the injury, there would be a tremendous increase in the quantity of the fluid. Later it became cloudy and finally purulent. Microscopic examination at this stage generally showed polymorphonuclear leukocytes and sometimes bacteria.

(e) Roentgen-Ray Examination: The roentgen ray was used in twenty-nine cases as an aid in the identification of the fracture. Four of these were craniotomies, and the examination was of great value in locating the bone lesion before the operation was performed. The other twenty-five cases were fractures from which the patient recovered under expectant treatment, and in all of them the diagnosis was made only by this means. More will be said about the applicability and the limitations of the roentgen-ray examination when these cases are discussed.

The patient was seen over a period of two years. Slow improvement took place, and he regained power in the right leg gradually. He was able to do heavy work, but there was some limitation of motion in the toes. The bone defect did not cause any trouble.

CASE 10.—V. N., a man, aged 25, was injured in collision between a truck and a street car. He was admitted to the hospital in a rational condition, but was drowsy and irritable. There was bleeding from the right ear canal, and the ear was split in a portion of the tragus. The spinal fluid was bloody. A few hours later, he became drowsier and more irritable. The deep reflexes were exaggerated, the left more so than the right. Blood pressure was 160 systolic and 120 diastolic. The pulse rate was slow, but full and bounding. A right subtemporal craniotomy was performed a few hours after admission, and an extensive egg-shell fracture was found in the temporal fossa. The bone was removed by rongeur forceps. A small amount of clotted blood and brain tissue was found external to the dura. As small spicules of bone had pierced the dura, a crucial incision was made in the dura. The brain bulged slightly and pulsated. Recovery was not eventful; pulsation at site of operation subsided, and the patient was discharged after twenty-six days in the hospital.

A month later, the patient complained that he was easily irritated by loud noises, had a headache and was dizzy. Three years later, he was reported as free from objective symptoms, but was unable to work in the city because he could not endure the noise.

#### CRANIOTOMY FOR THE RELIEF OF A DISABLING PARALYSIS

CASE 11.—R. C., a white woman, aged 36, was struck by an automobile and knocked against an elevated pillar. She was at another hospital for eleven days and then transferred to Bellevue. Shortly after admission, she showed a laceration of the scalp in the left temporoparietal region. There was a left facial paralysis of the upper motor neuron type. Roentgen-ray examination showed a stellate fracture of the left parietal region. On admission to Bellevue, the patient was semistuporous, restless and moved all extremities with the exception of her left arm, which was rigidly flexed on the chest. There was a left lower facial paralysis. The tongue protruded to the left. The symptoms were diagnosed as a possible injury to the right motor area. A craniotomy was performed in the right parietal region over the motor area nineteen days after the injury. A bone flap was turned down, the motor area exposed, a needle inserted in the arm area and some old blood obtained from the brain substance. Nothing further was done. The paralysis of the arm improved gradually, and the patient left the hospital on the fifty-third day after the injury.

At the end of two years, the patient did not show any particular symptoms except a slight spasticity of the left leg, but this was not troublesome. Otherwise she was in good condition.

The eleven cases in this series showed a variety of after-effects. One boy recovered and remained without symptoms (case 6). Two other patients also remained without symptoms, with the exception of the bone defect at the craniotomy site (cases 2 and 8). Three patients recovered without any other symptoms except some vague neurologic signs (cases 1, 4 and 7). One man (case 10) developed a marked psychosis, so he was unable to work.

*Indications for Craniotomy.*—The next point to determine was whether or not a craniotomy was necessary. In this series, thirty-four patients were subjected to this operation, and of these twenty-three died and eleven recovered. In every case there was a definite indication for the operation, which could be classified as follows: (a) compound or depressed fractures—fatal cases 3, recovery 7, total 10; (b) increased intracranial pressure—fatal cases 20, recovery 3, total 23; (c) local paralyses—fatal cases 0, recovery 1, total 1.

(a) Compound or Depressed Fractures: The reasons for surgical intervention in cases of compound fracture are obvious enough. Laceration of the scalp exposes the broken bones, and often hair and other infective material are present in the depths of the lesion. Conditions are right for the onset of a septic infection, and unless the fractured area is cleaned, death almost surely will result.

Depressed fractures are also sufficient in themselves to justify a craniotomy, even when the fracture is not compound. The bony fragments impinge on the adjacent portion of the brain, where they often cause direct lacerations of the cortex and sometimes produce definite disability.

The causes of the casualties in my ten cases were as follows: blunt instruments, 3; high falls, 3; falling objects, 2; automobile accidents, 1; bullet wound, 1. The trauma was such that an object with a limited area of impact in some way came into contact with the skull, causing a more or less localized lesion.

The ages of the patients showed two boys aged 14 and 15 years, four men aged 26 to 30 years, two men aged 44 years and two men aged 50 and 55 years.

The depressed portions of the fractures were situated in the left parietal region in three cases, in the right parietal in two and in the frontal region in five. A laceration was present in every instance, and in nine cases exposed the fracture. In one instance, the laceration did not make the fracture compound.

In the three fatal cases, hair and other foreign material were driven in among the fractured bones in two instances, while in the other case the bone was exposed freely. All died of an acute suppurative meningitis. Two were operated on early, and the infected material was removed, but the infection made its appearance on the third day, and death followed on the fifth. The other patient did not give any indication that he was in danger, but on the eighth day signs of meningeal irritation developed. Operation disclosed a severe frontal fracture with hair in between the bones and the septic process already present; he died on the ninth day.

The patients that recovered probably escaped because the infection was kept well under control. Six of these fractures were definitely compound. Two were operated on shortly after admission, and in one

Four patients, however, showed definite sequelae, which in all probability were referable to some lesion of the brain or some other complication of the fracture. These sequelae are shown in table 21.

In cases 3, 9 and 11, the muscular disability never disappeared entirely but improved as time went on. This suggests a brain injury in the cortex as the cause of the symptoms.

The craniotomy wound in the eleven cases caused scarcely any trouble, except in two instances. One man showed a pulsation at the site of the defect (case 1). In others, a deformity was left on the skull, notably a depression near the decompression window. One boy (case 5) actually returned to the hospital to have the defect successfully corrected by a cartilage transplant from the rib. Two others (cases 6 and 7) had the skull defect similarly reinforced at the operation, and the result was uniformly successful.

TABLE 21.—*After-Effects of a Compound Fracture and the Probable Cause*

	Disability	Probable Cause
Case 5	Total blindness of one eye, permanent	Cause unknown, but probably due to tear of optic nerve or injury of eyeball
Case 3	Persistent aphasia; motor speech	Probable injury of brain near island of Reil
Case 9	Loss of power in right leg which, however, improved	Probable injury to brain in motor area in left cerebral hemisphere
Case 11	Slight spasticity of left leg, not troublesome	Definite injury of brain in motor area in right cerebral hemisphere

#### RECOVERY UNDER EXPECTANT TREATMENT

Many patients with injury of the head were admitted to the hospital and recovered under expectant treatment, but it was questionable whether all of these had fractures of the skull. Unless a definite crack in the bone could be discovered by direct observation or by roentgen-ray examination, the case was eliminated from the series.

The total number of cases was twenty-seven. Two fractures were seen or felt through a laceration of the scalp in the frontal and right parietal regions, respectively. Another fracture of the frontal region was diagnosed by the presence of comminuted nasal bones, hematoma of the eyelids and a subcutaneous emphysema around the frontal region. The remaining fractures, however, were demonstrated only by the roentgen-ray examination; there were ten in the right parietal region, nine in the left parietal and five in the occipital region.

The preponderance of parietal fractures in the series was, perhaps, due to the fact that the roentgenogram shows cracks more readily in the lateral part of the skull than elsewhere, probably because the photographic field is easier to penetrate in this part than in the other regions.

of these hair was found between the broken bones (case 3). Trephine was performed on one patient on the second day over a compound fracture in the right parietal region, and later a craniotomy was performed in the left parietal region because the hematoma of the scalp began to increase in size at that point (case 4). One boy, aged 14 years, developed an infected compound fracture in the left frontal region, but the craniotomy on the fifth day served to stay the infection (case 5).

Another man, aged 28, fell down the hatchway of a ship and sustained a severe compound fracture of the frontal region, which extended into the frontal sinus. The operation was performed eight days later, and the patient recovered without any sequelae (case 2).

One boy, aged 14 years, had a fragment of bullet removed from the frontal region fourteen days after the shooting and also recovered without incident. This, however, was not remarkable, as the foreign body penetrated only the outer table and did not involve the inner table (case 6).

A man, aged 44, was operated on for a depressed fracture in the left parietal region which, however, was not compound. The fracture apparently produced definite weakness and convulsive jerking of the right leg; craniotomy on the fifth day relieved these symptoms in part (case 7).

Three of these cases produced definite abnormal neurologic signs, probably referable to a direct laceration of the adjacent portion of the brain. They will be considered in greater detail in the section on "follow-up."

A consideration of these ten cases sheds little light on why there should be infection in some and not in others. In some instances, a prompt operation failed to stave off the suppurative meningitis, while in others a delay of several days did not seem to cause any untoward effects. In addition, two compound fractures were described in the series of cases in which the patients recovered under expectant treatment. In general, the more the bone was broken and the more foreign material that was present in the wound, the greater was the likelihood of septic infection; some patients, however, apparently showed surprising resistance to severe injuries of this type.

(b) Increase of Intracranial Pressure: Twenty-three patients were operated on for the relief of intracranial pressure. Of these, twenty died and three recovered. The craniotomy in this type of lesion was not so effective as in cases in which depressed and compound fractures were the chief indications for operation.

Fatal cases. Here the points of emphasis were the general clinical picture which the patients presented in the hospital, the means by which the fracture was located and the different factors which encouraged the surgeon to try the craniotomy and to select the side of the head on which to operate.



As a means of diagnosis, the roentgen ray is valuable in some cases, but the possibility of error cannot be excluded. Many grooves occur in the skull normally, and it is not impossible that some of these may throw a shadow similar to a skull fracture. However, in this series positive diagnosis by the roentgen ray was accepted as proof of fracture.

The age and sex incidence are shown in table 22.

On admission to the hospital the symptoms were variable, but were generally those of a moderately severe cerebral concussion. Three patients were unconscious but recovered their senses a few hours afterward. The other twenty-four were conscious on admission to the hospital and more or less oriented; they were semistuporous, irritable, complained of headache, had vertigo, vomited, etc. Most of these patients gave a history of a period of coma immediately after the accident; in other instances, their condition after the accident was in doubt. One man said definitely that he was not unconscious.

TABLE 22.—*Cases that Recovered Under Expectant Treatment*

Age Incidence			
No. of Cases		No. of Cases	
10 to 20 years.....	5	40 to 50 years.....	4
20 to 30 years.....	4	50 to 60 years.....	5
30 to 40 years.....	8	60 to 70 years.....	1
Sex Incidence			
22 men		5 women	
Casualty Incidence			
Automobile accidents.....	6	Hit by falling object.....	2
Street car accidents.....	1	Hit by digger on coal barge.....	1
High falls.....	3	Elevator accident.....	1
Low falls.....	4	Beaten.....	1
Falls down stairs.....	3	Unknown.....	1
Thrown from vehicle.....	4		

Some of the patients improved without displaying any further symptoms, while others gave an indication that they were suffering from a mild grade of cerebral compression. This was shown in various ways—by a slow pulse rate, by increased pressure in the spinal fluid and by a variation in blood pressure from systolic 90 and diastolic 60 to systolic 150 and diastolic 70. The symptoms were never extremely severe, however. Sometimes the headache was localized, and this, together with vertigo and vomiting, was the only phenomenon recorded. None of the patients in this series showed a second lapse into unconsciousness so often described in the operative cases.

The external signs of injury were various. Lacerations of the scalp were present in twelve patients, contusions of the scalp in seven, hematomas of the eyelids in three, bleeding from the ear in five and from the nose two, vomiting of blood in three, blood in the posterior pharynx in one and subcutaneous emphysema of the frontal region in one. Five

It is worthy of note that twelve patients were admitted in deep coma and apparently in a serious condition. One of these gave a history of a lucid interval and relapse into coma a second time before he entered the hospital unconscious.

Four patients admitted in a conscious condition while in the ward rapidly became unconscious, thus demonstrating the onset of cerebral compression. Four patients were admitted in a partially stuporous condition and gradually sank deeper and deeper into the final moribund state.

The patients were operated on as follows: on the day of admission, 13; on the first day after admission, 1; on the second day after admission, 2; on the third day after admission, 1; on the sixth day after admission, 3.

As a general rule, the patients displaying the most acute symptoms were operated on as soon as possible, while others were trephined at a later date because they did not display frank signs of intracranial tension until just before the craniotomy was performed.

The external signs of injury helped to indicate, with a fair degree of accuracy, the point at which the violence was applied, but there were a few errors. An obvious laceration in one case was entirely distinct from the point of fracture, and this was explained by the fact that the head could be easily injured twice in the same casualty. However, the craniotomy site was selected on other grounds, and this furnished a check against a mistake.

The signs were: lacerations, 6; hematomas, 7; hematomas which increased in size, 1; hematomas and bleeding ear canal, 1; abrasions and bleeding ear canal, 2; bleeding ear canal, 1; no signs externally (fracture located by the roentgen ray), 1.

The presence of intracranial pressure was recognized in various ways—in many instances by a slow pulse, in some by high blood pressure, in others by pressure in the spinal fluid, in one case by increase in the size of the hematoma of the scalp, in another by profuse bleeding from a compound fracture and in four by the lapse of a conscious patient into coma while in the ward. The reliability of these various methods has already been discussed.

The neurologic signs were especially valuable in locating the site of the compression, though at times they led the operator into mistakes. The most convenient way to consider them is in connection with the complication which caused the death of the patient.

Unilateral epidural hemorrhages were demonstrated in eight instances. Two of the cases showed merely severe intracranial pressure, but not any definite neurologic signs. The other six, however, gave the following indications that the cerebral cortex was involved on one side:

cases did not present any sign of head injury. In the majority of instances, the external injuries gave a clue to the location of the fracture, but in some this connection was not obvious.

In two instances a sharply localized headache, once in the left parietal area and once in the occipital area, helped to indicate the probable site of the fracture, which was later confirmed by roentgen-ray examination.

The neurologic signs were indefinite. All the pupillary reflexes were normal. Examination of the eyegrounds revealed at most only a slight haziness or congested vessels. The normal reflexes were described as hyperactive, sluggish and sometimes unequal on the two sides. A few pathologic reflexes were described, such as ankle clonus, Babinski sign, positive Kernig sign, stiff neck, nystagmus, temporary facial paralysis and deviations of the tongue to one side. One woman showed a permanent foot drop, but there was reason to believe that this was caused by an injury to the peripheral nerve trunks. Most of these signs were temporary, and were not definite enough to encourage a craniotomy for the relief of the symptoms.

Examination of the spinal fluid revealed a bloody fluid in two or three tubes in eighteen cases (under pressure 10), a yellow tinged spinal fluid in 2, a spinal fluid at first bloody, then clear in 1, observations not recorded in 6. The blood in the fluid indicated that there was a sub-arachnoid hemorrhage of some kind which, in all probability, took its origin from an injury to the brain. The yellow tinged fluid occurred in two patients who entered the hospital several days after the trauma, and the lesion presumably was being transformed into a "plaque jaune" at the time of the lumbar puncture. One patient, as noted, showed blood in the spinal fluid on admission to the hospital, which later became clear, probably indicating complete healing of the brain injury.

The anatomic characteristics of the fracture and the intracranial lesion could only be surmised. Most of them appeared to be vault fractures which descended into the base. With the exception of one or two, it was impossible to say how many were comminuted. Two fractures were compound, but neither was infected, and it is difficult to explain why they should have healed without operation, while intracranial infection occurred in similar lesions.

Twenty-one patients ended their convalescence in from twenty to twenty-four days. Two were in the hospital only fourteen days, but had been injured several days previous to admission. Four patients remained from thirty to fifty days in the ward, but this was because they had other injuries, such as fractures of the forearm and the like. The usual term of convalescence seemed to be slightly more than three

Lateral linear fracture on the right side.

Epidural clot on the right side.

Deep tendon reflexes on the left more exaggerated than on the right.

Ankle clonus on the left more persistent than on the right.

The right pupil larger than the left.

Lateral linear fracture on the right side.

Epidural clot on the right side.

The right arm more spastic than the left.

Weakness of the left facial muscles.

Pupils not mentioned.

Lateral composite fracture on the right side.

Epidural clot on the right side.

Paralysis of the right facial muscles.

Extremities on the left more spastic.

The right pupil larger than the left.

Lateral linear fracture on the left side.

Epidural clot on the left side.

Paralysis of the right facial muscles.

Flaccid paralysis of the right arm and leg.

The right pupil larger than the left.

Lateral linear fracture on the right side.

Epidural clot on the right side.

Flaccid paralysis of the left arm and leg.

The right pupil larger than the left.

Lateral linear fracture on the right side.

Epidural clot on the right side.

Pressure on hematoma in the right mastoid region induced a clonic convulsion in both upper extremities.

The right pupil larger than the left. This, with a hazy eyeground on the right side, apparently determined the site of the craniotomy.

Apparently the pressure of the extradural hemorrhage over the motor area was the cause for the different neurologic reactions. In four instances the extremity muscles on the side opposite to that of the hemorrhage were involved in some way. One patient for some reason showed a paralysis of the arm on the same side as the epidural clot. The sixth case showed clonic convulsions in the upper extremities, which were induced by pressure over the right mastoid. In every instance the craniotomy successfully demonstrated the fracture and the hemorrhage.

The pupil was dilated on the side of the lesion in five cases, but was dilated on the opposite side in one case. The facial muscles reacted capriciously and were useful only as confirmatory phenomena.

Unilateral subdural hemorrhage was described in six cases. One man had every indication of severe intracranial pressure, but distinctive nervous phenomena were not present. The other five patients, however, showed some of the following definite reactions:

weeks. The impression was given that the active symptoms would clear up during that time if the injuries were going to heal spontaneously.

All of these twenty-seven patients were followed up for a greater or lesser length of time after discharge from the hospital ward. Nine did not show any symptoms. The other patients, however, complained of a great variety of symptoms, some of which were transient, while others lasted as long as the follow-up observation continued. Fifteen patients complained of headache and dizziness. Three others showed symptoms of a low grade psychosis, such as apprehensive feelings, poor memory, inability to concentrate, and the like. Undoubtedly many of these phenomena had an organic basis, but some were undoubtedly psychologic. Fractures of the skull are regarded with great trepidation by the laity, and there is a tendency to exaggerate the consequences of the injury. It was also difficult to say in any one case just what was caused by the fracture and what was the result of some other constitutional disability.

Six patients developed deafness in one ear, four on the right and two on the left side. There was reason to believe that the disability did not antedate the injury and was caused by the fracture line running through the ear structures in the middle fossa. Four showed bleeding from the auditory meatus on admission to the hospital, and five showed fractures involving the middle fossa in the ear region. The lesion which produced the deafness was never ascertained. Otoscopic examination of the ear drums was recorded in three cases, but only one patient showed a definite injury of the drum on the deaf side (see protocols).

In this connection, it was worth noting that two patients who showed bleeding from the external auditory meatus on admission did not subsequently complain of deafness in that ear. Fractures of the middle fossa not infrequently passed over the roof of the external ear, avoiding the deeper ear structures, but at the same time causing an aural hemorrhage by laceration of the mucous membrane of the external canal. This lesion would not necessarily cause deafness. One case in the list showed a temporary facial paralysis which, however, cleared up in six months after the patient left the hospital. The origin of the paralysis was not obvious (case 15).

One patient who was followed up complained of a greatly impaired sense of smell, which gradually improved as time passed. The history and clinical course in this case suggested that the disability was, in all probability, caused by lacerations on the under surface of both frontal lobes which involved the olfactory bulbs to a greater or lesser degree. Many necropsies showed numerous contre-coup lacerations of the orbital convolutions and the olfactory bulbs, and it was more than probable that this was the lesion in case 18.

*Causes of the Cerebral Compression**Neurologic Signs*

Lateral composite fracture on right side running across vertex.

Left subdural hemorrhage from contre-coup laceration.

Lateral composite fracture on the right side.

Right subdural hemorrhage from direct laceration.

Posterior linear fracture to foramen magnum.

Subdural hemorrhage on left from contre-coup laceration.

Lateral linear fracture on right side.

Subdural hemorrhage on left from contre-coup laceration.

Bilateral craniotomies were performed in both parietal regions.

Lateral linear fracture on right side. Large right subdural hemorrhage from contre-coup laceration.

Moderate sized epidural clot on left side.

Bilateral ankle clonus and Babinski sign more pronounced on the right side.

Deviation of tongue to the left side. Pupils dilated but equal.

Weakness of left arm and left side of face, manifest on second day.

Deep tendon reflexes and ankle clonus increased on left side.

Pupils slow to react but equal.

Clonic convulsions, right arm and leg, periodic. Later right arm became spastic and right leg flaccid.

Paralysis of left facial muscles.

Head turned to right, eyes to left.

At first, neck was rigid and left facial muscles showed clonus. Periodic convulsions later.

Clonic contraction of neck muscles on right and right arm.

Tonic spasm of left arm.

Legs—tonic spasm in extension.

Pupils equal.

All reflexes exaggerated on left side.

Left arm and leg spastic.

Right arm and leg flaccid.

Right pupil larger than left.

As noted in the foregoing, in three cases, abnormal reflexes, weakness of muscle groups, clonic convulsions and tonic contractures were present on the side opposite to that where the subdural hemorrhage was located. In another instance, the convulsions and the nervous phenomena were striking but not definite, so that bilateral craniotomies were performed. In another, the pupillary reactions and spastic paralyses in the muscles of the left extremity suggested a hemorrhage on the right, but the flaccid paralysis in the right extremities indicated lesions elsewhere. As a matter of interest, there was an epidural clot of moderate size in the left temporal region, which possibly explained the latter.

In all of these cases the operative field was selected with due regard to the signs, and the source of trouble was located successfully. The pressure of the hemorrhage probably caused the abnormal neurologic conditions, although in some instances lacerations of the brain undoubtedly had an effect.

Bilateral subdural hemorrhages were present in three cases from direct and contre-coup cerebral lacerations. In one man, with a lateral linear fracture on the right side, clonic convulsive seizures were noted in the right arm and face, while the left side of the body showed almost complete spastic hemiplegia. Another patient, with the fracture on the right side, showed spasticity in both arms and legs, especially on the



right, with the development of a right patellar and ankle clonus. Still another, with a left lateral fracture, showed a flaccid paralysis of the left arm and leg and a spastic right arm and leg. The fractures in all these cases were in the parietal region, and the operation was performed near the sites of fracture.

Two patients died of a suppurative meningitis. In one instance, the craniotomy was performed in the left parietal region because a definite paralysis was present on the right side of the body and the right pupil was larger than the left. There were also definite signs of increased intracranial tension. The operation disclosed a lateral linear fracture and a direct laceration of the brain cortex. The patient later developed the meningeal inflammation which was demonstrated by lumbar puncture. Necropsy was not performed, and the cause of the meningitis could not be ascertained.

The other patient admitted showed few symptoms besides bleeding from the left ear canal. Two days later the discharge from the ear became purulent; he also developed a generalized convulsion, a stiff neck and a bilateral Kernig's sign. Indications of increased intracranial pressure appeared, which encouraged the surgeon to attempt a craniotomy in the right parietal region on the sixth day. Nothing was found at operation, but a marked cerebral hernia developed in the operative field. The patient died shortly after the operation, and necropsy disclosed a lateral linear fracture of the left middle fossa involving the middle ear, with a severe otitis media, an abscess of the brain in the adjacent portion of the left temporal lobe and a suppurative leptomeningitis. It is probable that the abscess of the brain was responsible for the symptoms of intracranial pressure.

(b) Recovery after craniotomy: Three patients gave distinct signs of intracranial pressure but recovered after craniotomy.

The impression was gained from the histories that all three when admitted showed only a moderately severe degree of traumatic shock.

In one instance (case 8), the fracture was located in the right temporal region by the roentgenogram and the localized headache. Definite signs of intracranial pressure on the third day of the patient's stay in the hospital, together with an engorged eyeground and an abnormal reflex on the right side, seemed to indicate a right temporal craniotomy. When this was performed, an epidural clot was found and evacuated.

In a second case (case 9), the fracture was compound in the left parietal region, while a developing right hemiplegia indicated that the complication was present near the fracture. The spinal fluid was bloody and under tension, indicating increased cerebral compression. A left parietal craniotomy, performed a few hours after the injury, disclosed an epidural hemorrhage, which was controlled.



CASE 16.—J. O., a white woman, aged 25, was knocked down by a taxi. She was admitted in a stuporous condition, with tender spot just behind and above the left mastoid. She complained of severe occipital headache and ringing in the left ear. The spinal fluid was bloody on admission, but flowed out clear seventeen days later. At first, she showed definite nystagmus, an active patellar tendon reflex on the right and absent on the left. Roentgen-ray examination disclosed a fissure fracture of the right side of the occiput running to the foramen magnum and another fracture of the right border of the foramen magnum. She was discharged on the twenty-fourth day, still complaining of deafness and buzzing in the left ear.

One year later, she showed persistent deafness in the left ear, but no other symptoms.

CASE 17.—C. B., a white man, aged 27, was injured in an elevator accident. He was admitted in a semistuporous condition with pain in the back of his head. Bleeding from the right ear was present. The pupillary and tendon reflexes were normal. The spinal fluid was bloody but under normal pressure. Roentgen-ray examination disclosed a fracture in the right middle fossa, running into the right temporal and parietal bones of the vault. He complained of deafness in the right ear, which persisted to the day of discharge—twenty-four days later.

After two years, deafness persisted in the right ear, and the patient also had a low grade psychosis.

#### LOSS OF SENSE OF SMELL

CASE 18.—H. R., a white man, aged 43, was struck by a taxi. He was disorientated and drowsy on admission to the hospital, but he knew his name and address. He complained of headache and dizziness, especially on motion. External injuries were not noted. The pupillary reactions were normal, and the tendon reflexes were slightly hyperactive. The spinal fluid was bloody and under increased pressure. There was slight cloudiness in the right eyeground; the left was normal. The day after admission, the patient complained of right frontal headache, which persisted for three days. A slight ecchymosis developed in the right eyelid. Roentgen-ray examination showed a fracture in the right temporo-occipital region, extending about  $1\frac{1}{2}$  inches upward from a point  $2\frac{1}{2}$  inches behind the right auditory meatus. For a few days, his pulse rate was slow—about 68 to 80—with a blood pressure of 130 systolic and 80 diastolic. All symptoms finally cleared up, and on the twenty-fourth day the patient was discharged.

For a few months, he suffered from dizziness on sudden motion of the head and throbbing in the left ear. He also found that he had lost all sense of smell: at first, this was complete in the left nostril but only reduced in the right. This persisted, but gradually he was able to recognize odors. He found that he often noticed smells that were not present, such as the odor of creosote. Most odors were disagreeable to him. This did not have any relation to his physical condition, as he was well otherwise.

#### COMMENT

The sixty-one cases considered showed a preponderance of fractures in the lateral part of the skull, with relatively few located anteriorly and posteriorly. They were found as follows: lateral fractures, 48; anterior fractures, 7; posterior fractures, 6. The reason for this disproportion was probably that the lateral variety was more easily discovered by the roentgen ray than the other types, and also that this variety was accompanied by such characteristic external lesions as large hemor-

teal osteogenic sarcoma. The patient has remained well up to the present time, more than five years later. This case has been reported in the Bone Sarcoma Registry.

CASE 25.—*Sarcoma of tibia (clinical and roentgen-ray diagnosis), probably endothelioma; treated with toxin and radium; limb saved; patient well seven years later.*

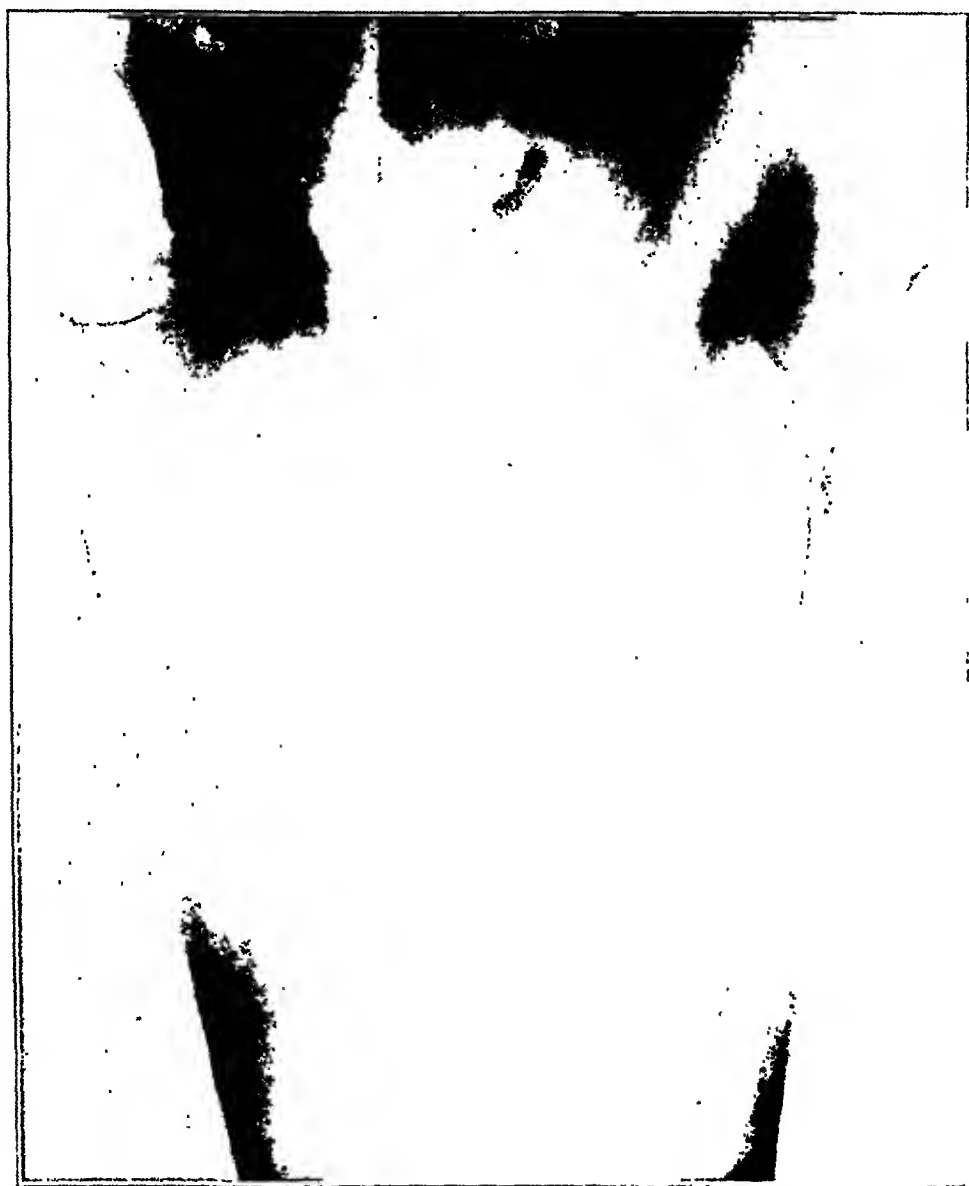


Fig. 51 (case 117 in table 7).—Periosteal sarcoma of femur after prolonged roentgen-ray treatment; death from metastases.

W. P., a man, aged 55, was referred to us by Dr. Alfred M. Rowley of Hartford, Conn., in July, 1919. Four years before the patient had fallen from a ladder; four days later he suffered a fracture of the upper portion of the tibia; the leg was placed in a plaster cast for three weeks. Two years later, while getting off a street car, he fell, fracturing the same tibia. Roentgen-ray examination

showed extensive bone destruction of the middle and upper portion of the shaft, involving both central portion and periosteum. No exploratory operation was done at the Memorial Hospital; he was treated with radium locally and the toxins systemically for several months. The fracture reunited, new bone formed, and when last heard from, in July, 1926, six years later, the patient was still in excellent condition.



Fig. 52 (case 117 in table 7).—Periosteal sarcoma of femur.

CASE 26.—*Periosteal osteogenic sarcoma of femur.* H. S., a man, aged 19, was referred to us by Dr. H. Hallarman of New York, April 23, 1920. The family history was negative. Four months before the patient had fallen but did not recall distinctly that he had injured the right knee. One month later he noticed pain in the right popliteal space, which was treated with local applications on the assumption that it was of rheumatic origin. Two weeks later he noticed a

rhages of the scalp or bleeding from the external ear canal. In addition, lateral fractures usually involved the motor cortex in various ways and thus produced striking neurologic signs, while anterior and posterior fractures, even when severe, tended to involve the "silent" areas of the brain and only occasionally elicited a definite neurologic phenomenon.

In general, with the exception of such outspoken indications as compound or depressed fractures, patients with the anterior and posterior group of lesions did not require operation in the normal course of events. They seemed either to cause complications which were almost inevitably fatal or else to be accompanied by such slight intracranial lesions that the patient recovered spontaneously.

Lateral fractures displayed these same characteristics to a certain extent, but at the same time produced a large number of intracranial injuries which were amenable to a craniotomy, but which invariably proved fatal if left alone. Accordingly, lateral fractures formed the vast majority of those in patients subjected to craniotomy.

#### SUMMARY

1. A number of clinical records were collected, and the reaction of the patient to the fracture of the skull during life was studied.

2. Many patients were admitted to the hospital in a moribund condition or lingered for several days in the hospital, finally dying of suppurative meningitis, pneumonia or sepsis. They were cases not suitable for operation because of the patients' poor physical condition and because of the absence of signs which indicated a specific condition that would be alleviated by craniotomy.

3. Sixty-one cases were studied in some detail. They were arbitrarily separated into the following categories: (1) patients on whom a craniotomy had been performed, thirty-four; twenty-three of these patients died and eleven recovered; (2) patients recovering under expectant treatment, twenty-seven.

4. Patients treated by craniotomy were subjected to rather rigid physical examination before the procedure was attempted. It was first necessary to determine the probable location of the skull fracture by a careful consideration of the history of the case, the observations elicited on clinical examination, the appearance of the spinal fluid, the types of external injuries present, and by roentgen-ray examination.

5. Then it was necessary to determine whether there were signs of an intracranial condition that made craniotomy advisable. In the thirty-four patients operated on, three indications for operations were discovered: (a) compound or depressed fractures of the skull (three patients died and seven recovered); (b) the presence of definite intracranial tension, especially if the lesion causing the trouble could be definitely localized



by neurologic examination (twenty patients died and three recovered), and (c) the presence of a disabling paralysis on one side (one patient recovered).

6. The twenty-seven patients who recovered under expectant treatment were all practically over the acute effects of the injury in from twenty to twenty-four days after the trauma. As a rule, they displayed only moderately severe symptoms of cerebral concussion and compression. The fracture was located by the roentgen-ray examination in twenty-four cases, through a compound fracture in two instances, and by subcutaneous emphysema of the frontal region in one. The neurologic examination and other signs were never definite enough to justify a craniotomy.

7. The patients who recovered were followed up for variable periods until it was felt that they had definitely recovered from the results of the fracture or until they disappeared from observation.

(a) The eleven patients who recovered under operation showed a variety of phenomena. Some were practically without after-effects or, at the most, displayed indefinite symptoms, such as headache or vertigo. One man developed a low grade psychosis. Four patients, however, had some definite disability, such as the loss of sight in one eye in one case, motor aphasia in another case and definite weakness in one leg in two instances. The motor disabilities improved but did not disappear entirely.

(b) Most of the twenty-seven patients recovering under expectant treatment did not show any severe after-effects, except vague symptoms of headache, dizziness, and the like. A few, however, had minor disabilities which could be attributed to definite lesions. Six were permanently deaf on one side, while one man showed a disturbance of the sense of smell.

As both the physical signs and the roentgen-ray interpretation were suggestive of a thickened pleura or encapsulated fluid at the right base, a thoracentesis was performed, but it was without result. Operative exploration was advised, but was refused by the patient, and she was discharged with the diagnosis resting between a localized empyema and a lung abscess with pleural involvement.

She was seen again in November, 1923, sixteen months later. Her condition had not changed, and further roentgen-ray studies showed the same obliteration of the cardiohepatic angle. She was again discharged untreated.

CASE 5.—F. L., a youth, aged 19, first seen in June, 1922, was referred from the United States Public Health Service with a diagnosis of bronchiectasis. His history included typhoid fever at the age of 10, lobar pneumonia at 15 and again eight months before the onset of his present illness, the removal of adenoids at the



Fig. 9 (case 4).—Atelectasis of the right lower lobe with chronic suppuration.

age of 9 and a tonsillectomy at the age of 16. He had not had any noteworthy cardiorespiratory symptoms before the present illness.

In 1921, the patient was stationed at an army flying field in Texas. His health was excellent until September of that year when, as a result of a "nervous breakdown" from overwork, he was placed in the camp hospital. After three weeks, he developed a "cold" accompanied by a cough and the expectoration of considerable watery, frothy sputum. This cough continued for some weeks, and he was finally discharged from the army in November because of "bronchitis." Returning to his home in Massachusetts, he remained for some time under the care of his family physician, and then entered a government hospital. During this period he raised approximately a cupful of slightly foul sputum a day. Careful studies were conducted to rule out tuberculosis. After several months of observation, during which he showed periods of remission followed by a return of symptoms, he was referred to the Massachusetts General Hospital.

On examination he presented evidence of loss of weight and strength; the breath was foul and there was definite clubbing of the fingers and toes. The right

# LOBAR ATELECTASIS IN CHRONIC PULMONARY SUPPURATION \*

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Observations on massive collapse of the lung and on other clinical conditions presenting extensive atelectasis enable us to offer a more complete description of the characteristic roentgen-ray shadow cast by a single atelectatic lower lobe, and to call attention to its association with certain cases of chronic pulmonary suppuration. Lobar atelectasis has been identified by Manges<sup>1</sup> through roentgen-ray observations in cases of obstruction of the air passages by foreign bodies. It has been observed in postoperative massive atelectasis of the lung by Jackson and Lee<sup>2</sup> and by Churchill.<sup>3</sup>

## ROENTGEN-RAY OBSERVATIONS IN LOBAR ATELECTASIS

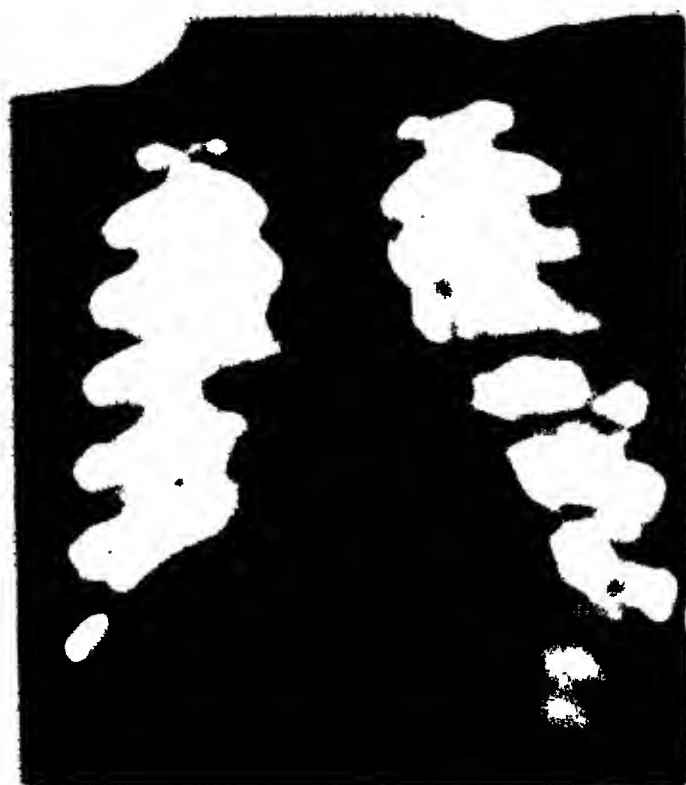
A deflated lobe of the lung is commonly pictured as a small puckered mass retracting to the hilum by means of a bellows-like shortening of the bronchi. This is what happens when the deflation occurs as the result of pneumothorax or pleural effusion; but when it is produced by bronchial obstruction in a chest with an intact pleural cavity, a different picture is presented.

The shape which a deflated or atelectatic lobe takes in the latter case is molded to conform to the adjacent lobes and structures and is determined by its inherent elasticity. The characteristic outline of an atelectatic lobe has already been demonstrated<sup>4</sup> by a roentgenogram of an autopsy specimen after its removal from the body. The shape assumed by a collapsed lower lobe is roughly that of a right-angled triangle, the base of which rests on the diaphragm. The apex is held at the hilum by bronchial attachments, and the hypotenuse shows as a sharply defined border which extends from the hilum to the diaphragm near the costophrenic angle.

Although the cases of postoperative massive atelectasis usually described show involvement of an entire lung, certain cases with a

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lobar distribution of the collapse have been observed. The roentgenograms of two such cases have been reproduced in a previous paper by one of us. In the first case there described,<sup>5</sup> the lobar collapse persisted as a residual condition after the other lobes were reinflated; in the second case,<sup>6</sup> the collapse when first observed was confined to the lower lobe.

It has been shown by Jackson and his co-workers that although the lodgment of a foreign body in a bronchus may produce hyperinflation under certain circumstances, complete obstruction causes deflation of the portion of the lung to which the bronchus is contributory. There



Fig. 1.—Atelectasis of the right lower lobe from the impaction of a meat bone in the bronchus.

may also be an attendant “drowning” of the lung and bronchial tree by the retained secretions. The roentgenogram reproduced in figure 1 shows a patient with a meat bone impacted in the bronchus of the right lower lobe. It shows the characteristic shadow of lobar collapse.

A tumor of the bronchus may by its growth so occlude the lumen as to produce complete atelectasis of a lobe. The roentgenogram reproduced in figure 2 is that of a patient with a primary squamous cell carcinoma obstructing the bronchus to the right lower lobe. The diagnosis was made on the basis of the history and roentgen-ray observations and confirmed by a bronchoscopic examination by Dr. D. Crosbie Greene. As in cases of massive collapse of the lung, the shadow of the collapsed

5. Churchill, Edward D. (case 1, fig. 2).

6. Churchill, Edward D. (case 2, figs. 3 and 4).

The patient made an uneventful recovery and was discharged unrelieved, with a diagnosis of bronchiectasis.

CASE 6.—L. D., an Italian girl, aged 9, complained of having had a mild, unproductive cough for six months. During this period she had also had an occasional pain in the chest and night sweats once or twice a week. Three months before admission to the hospital, she was awakened by a slight cough and found her mouth full of bright red blood. When a second hemorrhage of the same type occurred, she was brought to the hospital.

The child was undernourished and showed a slight secondary anemia. She held her head toward the left, apparently due to a spasm of the sternomastoid muscle. The left side of the chest was less prominent than the right but showed good expansion. There was relative dullness throughout the left side of the chest, growing more marked toward the base. The breath sounds on the left became bronchial and more distant from the ear as the base was approached. Just beside the spine at the base the breath sounds were close to the ear. There was marked

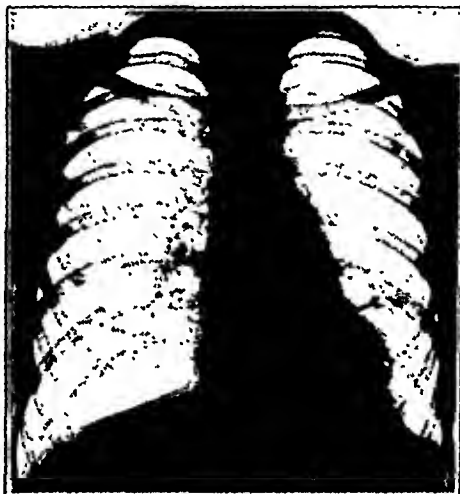


Fig. 11 (case 6).—Atelectasis of the left lower lobe with chronic suppuration. The arrow indicates the border of the lobe which lies behind the heart shadow by which it is nearly obscured. The displacement of the heart toward the affected side aids in the diagnosis.

clubbing of the fingers. Examination of the sputum failed to show tubercle bacilli and the Pirquet reaction was negative.

Roentgen-ray examination showed a high diaphragm on the left, which was limited in its excursion. A triangular area of dullness with a sharply defined border was detected behind the heart. This was interpreted as a localized destructive process near the root and base of the left lung, probably an abscess.

The child was kept under observation for two weeks, during which time her temperature was constantly elevated. A later examination of the chest proved that the small area of egophony and loud tubular breathing beside the spine at the left base disappeared on quiet respiration, only to reappear on coughing or with deep inspiration. This suggested intermittent bronchial obstruction. No notable change took place during her stay in the hospital, and she was discharged untreated with a diagnosis resting between chronic bronchopneumonia and lung abscess.

lobe obliterates the cardiophrenic angle, its upper border extending as a sharply defined line from the diaphragm to the hilum.

These observations, supported by further evidence obtained from the cases to follow, make it apparent that an atelectatic lower lobe appears in the roentgenogram as a triangular opacity which obliterates the cardiophrenic angle on the right, but is largely obscured by the shadow of the heart on the left. The apex of the triangle lies at the hilum, and the hypotenuse extends outward and downward either to merge with the shadow of the diaphragm or to meet the chest wall near the costophrenic angle.



Fig. 2.—Atelectasis of the right lower lobe from the obstruction of a primary carcinoma of the bronchus.

#### REPORT OF CASES

Roentgen-ray examination in the following cases of chronic bronchopulmonary suppuration showed the shadow of a deflated lower lobe.

CASE 1.—F. S., a girl, aged 18, with an uneventful past history, became ill on Dec. 12, 1923, with chills, fever and an unproductive cough. After a few days in bed she raised a small amount of thick, greenish sputum. Two weeks later, positive cultures were obtained from her throat, and she was taken to the diphtheria ward of the Boston City Hospital. There she developed a postdiphtheritic paralysis which caused her to remain for some five weeks.

During this period she had a cough, and the amount of sputum increased to several cups a day. It gradually became foul. After three months in another hospital, she entered the Massachusetts General Hospital in June, a little more than six months after the beginning of her illness. Her condition had been stationary for four months, the chief symptom being the production of about 15 ounces of foul, purulent sputum a day.



Examination showed that she was fairly well nourished, with a foul breath and an almost constant cough. There was definite clubbing of the fingers of both hands. Over the back of the right side of the chest, there was dullness from the angle of the scapula to the base. The breath sounds were bronchial at the top of this area, but absent at the base. There was egophony from the angle of the scapula downward. Vocal and tactile fremitus were increased in this region, and râles were not evident. The sputum was negative for tubercle bacilli, and bacteriologic examination showed it to be more suggestive of bronchiectasis than of lung abscess.

Roentgen-ray examination of the chest (fig. 3) showed evidence of "consolidation at the right base involving the entire lobe." Evidence of cavity formation was lacking. The heart was displaced toward the affected side. These observa-

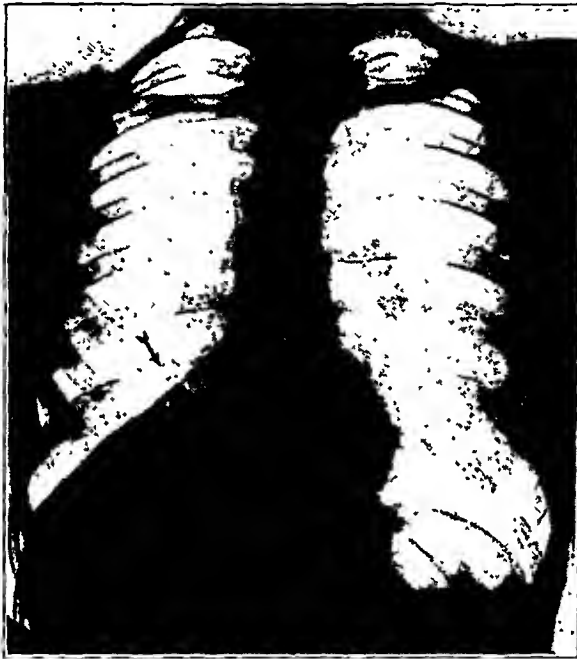


Fig. 3 (case 1).—Atelectasis of the right lower lobe with chronic pulmonary suppuration following postdiphtheritic paralysis.

tions at the time were thought to be consistent with an obstruction of the bronchus by a foreign body, pneumonic consolidation or abscess formation.

An operation was performed by Dr. Wyman Whittemore on June 19. The pleural cavity was found to be free from adhesions, with the exception of a few fibrous bands between the lower lobe and the diaphragm. The right lower lobe was small, of firm consistency and a dusky blue. The upper lobes were of normal appearance. At the first operation the lower lobe was walled off from the pleural cavity; following its removal a week later, the patient died.

Bronchial obstructions were not found in the excised lobe. The bronchi were filled with purulent exudate, and their walls were described as dilated<sup>7</sup> and surrounded by round cell infiltration.

7. A statement that a bronchus is dilated should be based on a consideration of the diameter in relation to the distance from the hilum, and not in relation to the proximity of the pleural surface or of other bronchi of similar diameter when

This evidence leads us to believe that deflation of a portion of the lung may in itself be a causal factor in the development of a chronic suppurative process. Such deflation has been observed most commonly with the lodgment of a foreign body in a bronchus, but we believe that it may also find origin in the so-called massive collapse of the lung. Atelectasis and fibrosis develop subsequent to the occlusion of a branch of the pulmonary artery, as has been shown experimentally by Schlaepfer.<sup>8</sup> We have observed here one instance in which chronic pulmonary suppuration developed following a postoperative infarction, apparently through these changes rather than through necrosis and sequestration of the involved area. None of the clinical cases cited here gave a history suggesting the occurrence of a postoperative pulmonary infarction of such magnitude.

As the cough and sputum of these patients are apparently due to intrabronchial stagnation in an area of lung which is already deflated, it would seem illogical to employ therapeutic measures which are designed to act by further compression, such as pneumothorax or thoracoplasty. If our concept of the pathologic process is correct, it would seem reasonable to treat these patients by bronchoscopic drainage in an attempt to obtain reexpansion, and if this method fails, by actual resection or destruction of the involved lobe by cautery. It is of interest to note that the patient in case 2 continued to raise over a pint of sputum a day, although the involved area of lung was compressed by the massive hydrothorax which complicated the therapeutic pneumothorax. In case 3 the alleviation of symptoms was greatest following the reexpansion of the lung after the pneumothorax treatment was discontinued, and the final roentgen-ray examination showed reexpansion of the involved lobe.

#### SUMMARY

The roentgen-ray observations in lobar atelectasis are described.

Six cases of chronic pulmonary suppuration are presented which show lobar atelectasis.

This association may be explained either as atelectasis secondary to a focus of pulmonary suppuration, or, as we suggest, as chronic intrabronchial stagnation superimposed on a primary atelectasis. Such primary lobar atelectasis is found in the so-called massive collapse of the lung, and four of our six patients date their symptoms from incidents known to be commonly associated with this disorder.

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8. Schlaepfer, Karl: Ligation of pulmonary artery of one lung with and without resection of phrenic nerve, *Arch. Surg.* 9:25 (July) 1924.

CASE 2.—M. D., an Italian youth, aged 18, gave a history of double pneumonia at the age of 5. He had been in bed for three months during a prolonged convalescence, and since that time had been subject to colds and bronchitis, particularly in the winter. He dated his cough and sputum, however, to a serious illness following an attack by two dogs five years before coming to the hospital. He was severely bitten about the buttocks and on the body, and was confined to bed for several weeks.

He was first examined in May, 1922, when he complained of a productive cough. There were musical râles at the bases of both lungs, and physical examination revealed that the cardiohepatic angle was obliterated. In December of the same year, he contracted a severe cold attended by an increase in the cough and in

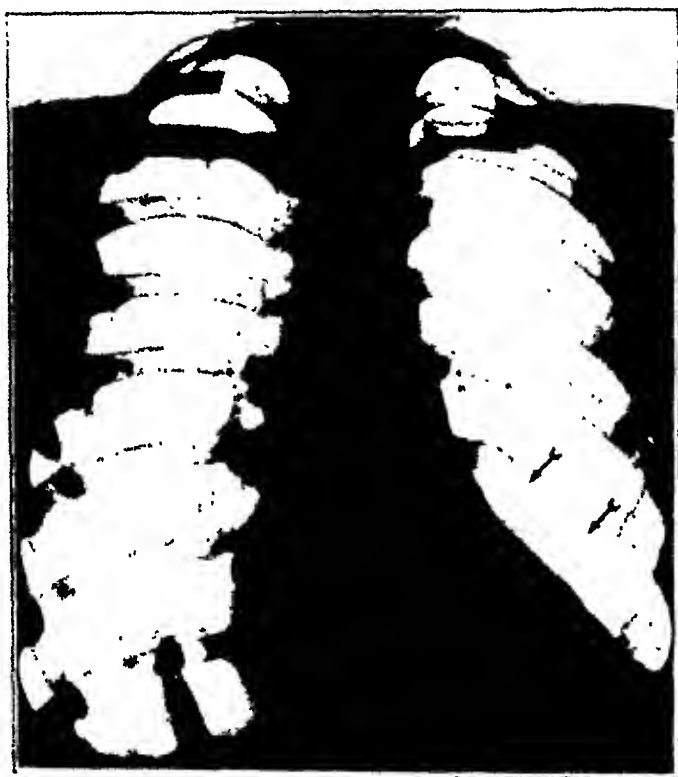


Fig. 4.—Atelectasis of the right lower lobe with chronic pulmonary suppuration (case 2). The displacement of the heart to the affected side is more marked than usual.

the amount of sputum. The latter gradually increased to a cupful a day. It became very foul and was at times streaked with blood after a severe attack of coughing.

seen in cross-section. A cross-section through a collapsed lobe shows a cluster of large bronchi lying in close proximity to each other and to the visceral pleura. Such a picture in an inflated lobe would indicate a pathologic enlargement of their diameters, but in a collapsed lobe must be interpreted with caution. This point will be made clear by reference to figure 1 in the article referred to in footnote 3, where the bronchi in a collapsed lobe are outlined by the roentgenographic density of the surrounding vessels. It is also important to bear this fact in mind in the interpretation of a picture of collapse of the bronchial tree, as such a cluster of bronchi in a normal size may give the impression of a large dilatation.



# Progress in Orthopedic Surgery

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## THIRTY-SECOND REPORT OF PROGRESS IN ORTHOPEDIC SURGERY \*

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### CONGENITAL DEFORMITIES

*Congenital Dislocation of Hip.*—From a study of 349 cases of congenital dislocation of the hip, Engelmann<sup>1</sup> is led to the conclusion that heredity plays a large part in the etiology. He describes the architectural similarity which he found in the pelvic bones of different members of one family, and he believes that the bony features which conduce to mechanically weak joints may likewise be transmitted to descendants. In 253 cases he was able to demonstrate, in addition to the dislocation of the hip, other congenital lesions, most frequently clubfoot.

Ryerson<sup>2</sup> believes that much of the difficulty in maintaining reduction of the hip in infants after manipulation may be avoided by the use of removable celluloid casts. These are not affected by the contamination of urine and feces, may be washed, and possess other obvious advantages over plaster.

Adams<sup>3</sup> describes the obstacles to reduction which were found at operation in a case of bilateral dislocation of the hips in which manipulative reduction had previously been attempted without success. On one side a strong transverse band was found in the front of the capsule,

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\* This Report of Progress is based on a review of 349 articles selected from 442 titles dealing with orthopedic surgery appearing in medical literature between July 24, 1926, and Nov. 7, 1926. Only those papers that seem to represent progress have been selected for note and comment.

1. Engelmann: *Zentralbl. f. Chir.* 51:3242, 1926.

2. Ryerson, E. W.: *J. Bone & Joint Surg.* 8:517 (July) 1926.

3. Adams, Z. B.: *J. Bone & Joint Surg.* 8:507 (July) 1926.

The patient lost weight and strength steadily during the next five months. A roentgenogram (fig. 4) showed marked dulness in the lower portion of the right part of the chest, with a sharply defined upper border extending downward and outward from the hilum to the axillary margin, obliterating the shadow of the diaphragm and the outline of the right border of the heart. This appearance was thought to be due to a chronic destructive process involving the right lower lobe and causing retraction of the heart and mediastinum to the right. It was remarked that occlusion of a bronchus might produce such a picture.

When he was admitted to the hospital in August, 1923, he was raising from 6 to 15 ounces of foul green sputum a day. On examination this showed many influenza bacilli, intracellular and extracellular; diphtheroid bacilli and a few intracellular streptococci. Repeated examinations failed to show tubercle bacilli.



Fig. 5 (case 2).—Injections of iodized oil, showing the saccular dilatation of the bronchi of the collapsed lobe in the presence of a therapeutic pneumothorax. (Injection mass traced with ink.)

Examination of the chest showed that the heart was displaced to the right. There was dulness in the lower portion of the chest with increase of fremitus and bronchial breathing. A diagnosis of bronchiectasis was made after a prolonged study to rule out tuberculosis.

Artificial pneumothorax was induced by Dr. Balboni and increased by refills until the lung was completely collapsed. As the lower lobe remained in contact with the diaphragm in its inner half, it is probable that there were some adhesions in this region. There was a reduction in the amount of sputum for a few months, but later the patient began to raise about 10 ounces a day. The amount of sputum continued the same, even when a complicating pleural transudate almost filled the right part of the chest. The fluid was aspirated from the pleural cavity many times, and unsuccessful attempts were made to reexpand the lung with view to a

and this had to be divided before the hip could be reduced. On the other side, bands were found along the inferior portion of the acetabulum, possibly representing a thickened cotyloid ligament. When this band was divided, as well as the reflected tendon of the rectus muscle, the hip was easily reduced. The postreduction roentgenograms showed both femoral heads deep in their sockets.

Galloway <sup>4</sup> reports the results of thirty-eight cases of congenital dislocation of the hip treated by open operation. He feels that the open operation is simple, safe, and reliable, particularly in children under 3 years of age, who have never been subjected to treatment by manipulation or otherwise. He classifies his results as follows: cured, 15; good results, 18; doubtful results, 5; known failures, none. The oldest child in this group was 2½ years old, and the youngest 17 months; none of them had been subjected to previous attempts at manipulative reduction. The author emphasizes particularly that the ideal age for the open operation is from 20 months to 2 years, and that the disturbance of the tissues by previous unsuccessful manipulative efforts renders the complete success of the open operation much more doubtful.

Balensweig <sup>5</sup> reports the end-result in a case of congenital dislocation of the hip in a girl, aged 13. After preliminary traction for three weeks, an open operation was performed. A new acetabulum was made in the upper half of the old shallow acetabulum, the head was reshaped and placed in the new socket. One year later, the patient showed satisfactory function; the shortening was reduced from 2½ inches (6.27 cm.) to 1¼ inches (3.1 cm.); there were 55 degrees of motion in flexion; 10 degrees of abduction and 15 degrees of internal rotation.

[ED. NOTE.—The orthopedic world has for some time been looking forward to the publication of end-results in the treatment of congenital dislocations of the hip by Galloway, the apostle of open reduction. The figures which he gives are impressive. There are no failures, and all results are classed as good with the exception of five, which, because they cannot yet be definitely appraised, are classified as doubtful. The group is small when compared with some other groups of end-results that have been published, but we know of none so large without any failures. It is to be noted that the age of the group varied from 17 to 30 months, and the point particularly stressed is absence of previous attempts at reduction. The results are less good when operation is performed only after manipulative failure. The absence of mortality attests the skill of the operator. It seems to us that Galloway's results support his contentions and that they constitute a challenge to the advocates of manipulative reduction.]

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4. Galloway, H. P. H.: *J. Bone & Joint Surg.* 8:539 (July) 1926.

5. Balensweig, I.: *J. Bone & Joint Surg.* 8:534 (July) 1926.

radical surgical procedure. In November, 1925, Dr. Greene examined him with a bronchoscope and did not find any evidence of bronchial obstruction. An injection of iodized oil, 40 per cent, into the right lower lobe in the presence of the pneumothorax showed the saccular cavitations characteristic of loculated abscess (fig. 5).

The pleural cavity ultimately became infected from a spontaneous puncture at the site of a needle puncture. After drainage of the empyema the patient's condition improved for a time, but he died following the first stage of a thoracoplasty.

CASE 3.—V. W., a housewife, aged 51, was operated on at another hospital in February, 1922. A curettage, suspension of the uterus, removal of an infected ovary and routine appendectomy were performed under ether anesthesia. Imme-



Fig. 6 (case 3).—Lobar atelectasis with chronic suppuration.

*Congenital Absence of the Tibia.*—Congenital absence of the tibia is one of the rarest congenital malformations and the rarest malformation of the lower limb. According to Evans and Smith,<sup>6</sup> the number of recorded cases is now 105. Absence of the tibia is rather more commonly total than partial, unilateral than bilateral, and right-sided than left-sided. Other abnormalities are frequently associated, but rarely is there any evidence of fetal disease. Disarticulation at the knee, followed by the application of a peg leg or artificial limb, the authors believe, is the best line of treatment. Conservative operations are indicated only in cases of partial defect, when the gap is small and limited to the middle portion or distal end of the tibia.

[ED. NOTE.—Although disarticulation at the knee usually gives a less satisfactory functional result than amputation above the femoral condyles, in this type of case it would appear to be the operation of choice on account of the necessity of saving the lower femoral epiphysis for the sake of growth. If necessary, reamputation can be performed after the patient reaches adult life.]

#### TUBERCULOSIS

*Paraplegia with Pott's Disease.*—Sorrel and Sorrel-Dejerine<sup>7</sup> have made a study of forty-two cases of paraplegia caused by Pott's disease in children and adults. On the basis of the clinical picture and the evolution of the disease, they were able to distinguish three different types of paraplegia. The first is the transient type, which clears up in a few weeks or months. It is of rare occurrence. The second type is also curable, but may persist for from eighteen to twenty-four months. It appears at an early stage of the tuberculous spondylitis, the development of the paraplegia is rapid and complete, and the clinical picture appears grave. Nevertheless, with proper treatment the paralysis disappears without any sequelae. The third form is an incurable paraplegia and appears as a late complication, often three years after the onset of the disease. It develops slowly and is never complete. It is compatible with a long existence. The curable forms are observed in adults as well as in children. They are induced by intraspinal abscesses, while the incurable form is the result of an external pachymeningitis, which causes so much destruction in the spinal cord that restoration ad integrum is impossible. The transient type of paraplegia is probably caused by edema of the dura mater without the formation of an abscess. The authors consider the prognosis more grave in a paraplegia starting with a mild clinical picture than in one with severe and rapidly developing manifestations.

6. Evans, E. L., and Smith, N. R.: Arch. Dis. Childhood 1:194 (Aug.) 1926.

7. Sorrel, E., and Sorrel-Dejerine: Presse méd. 34:785 (June 23) 1926.



Fig. 7 (case 3).—After a partial pneumothorax. The outline of the affected lobe is thrown into relief by the surrounding air. The upper arrow denotes the border of the partially collapsed upper lobes, which show a noteworthy difference in density in contrast to the lower lobe.

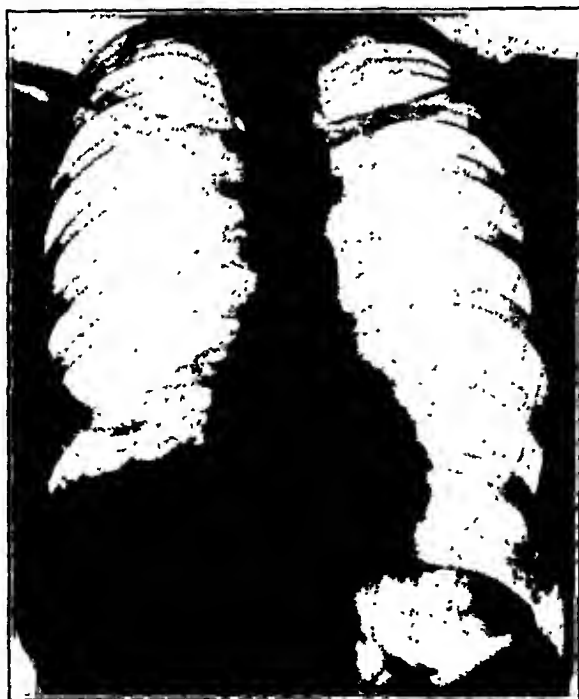


Fig. 8 (case 3).—After discontinuance of the therapeutic pneumothorax. The cardiophrenic angle is still hazy, but both the right border of the heart and the entire extent of the diaphragm are visible.

A pathologic study of four specimens of tuberculous disease of the spine with abscess, recovered at autopsy, has convinced Willis<sup>8</sup> that the lesions of the vertebrae are more extensive than has been claimed. In addition to the destruction of the bodies of the vertebrae, there is frequently involvement of the articular and transverse processes. There may be diffuse extension of the disease without any kyphosis or other deformity. Coexistent with extensive destruction of bone, there may be an appearance in the roentgenogram of merely superficial erosion. Productive changes in the bone are to be found in active lesions as well as in old healed spines. He urges the necessity for a thorough roentgen-ray examination and a search for multiple lesions.

*End-Results of Tuberculosis of the Knee Joint.*—Martens<sup>9</sup> has made a study of 211 patients with tuberculosis of the knee joint who were treated during a period of ten years at the surgical clinic in Goettingen (Stich). Eighty-nine patients were treated without operation, 105 patients had resection of the knee, and in eleven cases primary amputation was performed. The nonoperative treatment consisted of fixation by plaster casts, and, in certain cases, of aspiration and the injection of iodoform. Of the patients so treated, eighteen were cured with restoration of good function, six were cured without ankylosis, and twenty-one showed poor results. Of the cases of resection, eighty-eight patients were cured, although some required second operations; twenty-four patients were not cured, underwent secondary amputations, or died. The late results were good in sixty-four cases and poor in eleven cases. Only six patients showed shortening of more than 5 cm. after the resection. The percentage of cures is 77 per cent. He concludes that the decision as to whether a patient should be treated operatively or nonoperatively is an individual problem which must be settled on its merits in each case.

[ED. NOTE.—We note that a much higher percentage of end-results was obtained in the cases in which there were operations than in the cases in which operations were not performed. One cannot, therefore, make an accurate comparison between the two groups. It is also to be suspected that the diagnosis may have been in error in a certain number of the eighteen cases in which the patients are reported cured with good function.]

*New Method of Hip Function for the Treatment of Tuberculosis of the Hip Joint.*—Hibbs<sup>10</sup> describes a new method for extra-articular fusion of the hip joint. The essential feature of this method is a transposition of the trochanter so that it makes contact with the ilium above

8. Willis, T. A.: Surg. Gynec. Obst. 43:285 (Sept.) 1926.

9. Martens, Fr.: Beitr. z. klin. Chir. 135:631, 1926.

10. Hibbs, R. A.: J. Bone & Joint Surg. 8:522 (July) 1926.

swelling on the outer aspect of the femur just below the knee joint; this steadily increased in size. The pain became very intense necessitating two treatments with small doses of radium before the patient was admitted to the hospital.

Physical examination at the time of his admission to the Hospital for Ruptured and Crippled showed enlargement of the lower end of the femur most marked in the region of the outer condyle, extending to the popliteal space and



Fig. 53 (case 121 in table 7).—Periosteal sarcoma of shaft of femur of unusual malignancy. Roentgen-ray treatment was given for six weeks; amputation was followed by metastases in four weeks.

upward for a distance of 3 inches (7.6 cm.). It was apparently of bony origin, firm in consistence but not of bony hardness. The leg could be flexed almost to a right angle. The pain had diminished somewhat since the radium treatment. The patient was put on systemic injections of the mixed toxins at once; these were continued three or four times a week. At the end of three weeks there was definite decrease in the size of the leg. The injections were continued regularly until



early J. when a slight increase in the size of the tumor was noticed. He was transferred to the Memorial Hospital, where the radium pack was applied, a total of 20,958 millicurie hours over two areas at 6 cm. distance.

He returned to the Hospital for Ruptured and Crippled and the toxins were resumed in doses up to 24 minims without marked reaction. While the tumor

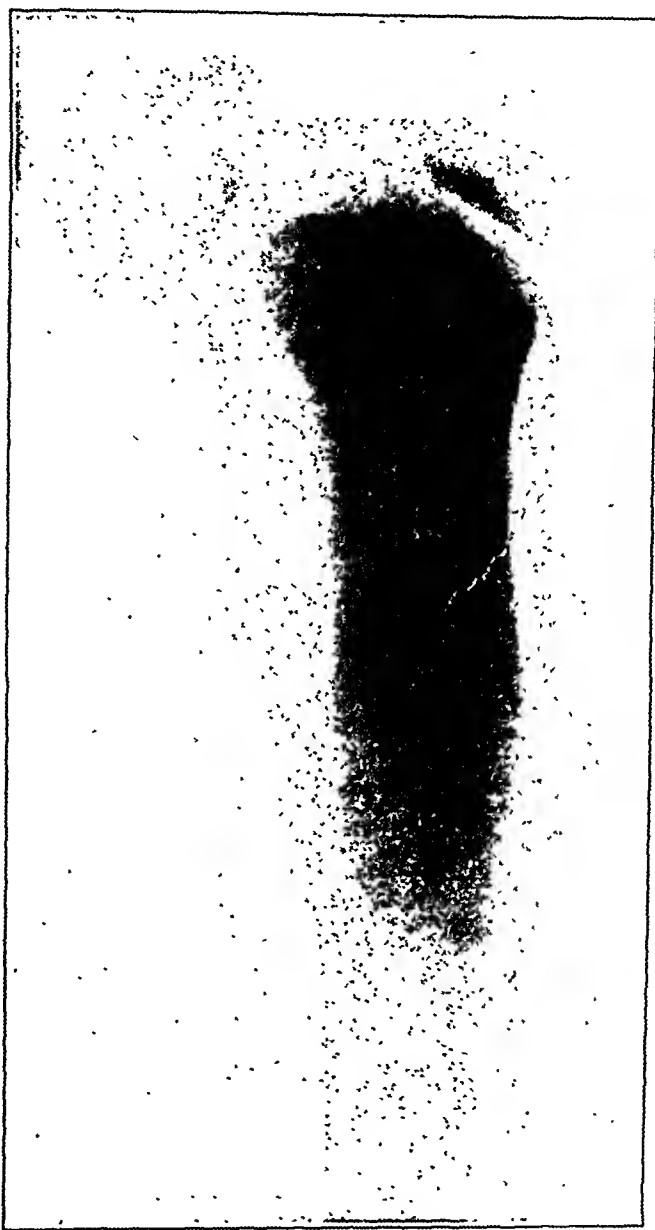


Fig. 54 (case 121 in table 7).—Periosteal sarcoma of shaft of femur.

showed some diminution in size, the improvement was only temporary, and it again began to increase. There was considerable synovitis, and the roentgen rays showed an extension of the disease higher up in the femur with an increase in thickness and greater destruction of the dense tissue of the bone itself. The patient finally consented to an amputation, which was performed by one of us, just below the trochanter, in August, 1920.

Microscopic examination was made by Dr. F. M. Jeffries, who reported periosteal neoplasm, apparently originating in the popliteal region and extending nearly

and with the femur below, securing continuity of periosteum. He reports the results in the first twenty cases; eighteen of these patients have definite fusion, shown by physical and roentgen-ray examination. The ages of the patients vary from 4 to 31 years; the first was operated on April 5, 1923. The average duration of the disease before operation was eight and one-half years; the shortest, six months; the longest, twenty-six years. The one death was that of a man, aged 21; he died nine months after operation from miliary tuberculosis. These twenty patients had been treated at the New York Orthopedic Hospital for an average of six years, and some had been treated for years in other hospitals. Six had been treated at the country branch for periods of from three to seven years. In cases of severe flexion and adduction deformity, this is not corrected at the time of the operation. Subtrochanteric osteotomy was performed in one case and may be necessary in others, but not until the extra-articular fusion is complete.

#### POLIOMYELITIS

*A Milk-Borne Epidemic.*—Knapp, Godfrey and Aycock<sup>11</sup> have made a study of an epidemic of poliomyelitis which occurred in the city of Cortland, N. Y., the circumstances of which pointed strongly to a contamination of milk supply as the cause. From Dec. 14, 1925, to Dec. 25, 1925, eight cases developed. These were the first to occur subsequent to the appearance of three cases more than two months before. All the patients were found to have consumed milk from the same dealer. On December 7, seven days before the onset of symptoms in the first patient of this group, a 16-year old boy who was working on the dairy farm milking the cows and handling the milk, became ill with poliomyelitis. The time which elapsed between the first mild appearance of his symptoms and the development of the later cases is consistent with the generally accepted minimum and maximum incubation periods of poliomyelitis. While this outbreak points strongly to transmission through the milk, the authors are not of the opinion that this is the usual mode of spread of the disease.

*The Kansas City Epidemic of 1925.*—Diveley,<sup>12</sup> in reporting the epidemic of infantile paralysis of 1925 in Kansas City, states that fifty-one cases had been reported after the lapse of four months. Of these, seventeen, or 33 per cent, died; two, or 4 per cent, recovered without residual paralysis, and nineteen, or 37 per cent, showed paralysis of varying degrees, and all the latter group have residual paralysis at the present time, about 50 per cent reporting improvement. Diveley feels that the patients treated with Rosenow's serum showed a more rapid

11. Knapp, A. C.; Godfrey, E. S., and Aycock, W. L.: Outbreak of Poliomyelitis. Apparently Milk Borne, J. A. M. A. 87:635 (Aug. 28) 1926.

12. Diveley, R. L.: J. Missouri M. A. 23:237 (July) 1926.

*Pulsating Tumors in Bone.*—Alessandri<sup>35</sup> reports his observations on three cases of pulsating tumors of bone and one nonpulsating tumor caused by metastasis from hypernephroma. He has collected from the literature additional cases to make ninety-two in all, of which eighty-six were hypernephroma and six were tumors of the suprarenal capsule. His conclusions are as follows: 1. Metastases in the skeleton may come from neoplasms of various organs, but the most common are from epithelial tumors of the breast, prostate, thyroid and suprarenal gland. 2. Pulsation sometimes occurs in metastatic tumors from the thyroid, but more frequently in those from the suprarenal gland. Eighteen of these have been observed. 3. In thyroid tumors the metastases may be exclusively in the skeleton and may be single. The metastases from suprarenal tumors may also be single. 4. In suprarenal tumors the metastases may appear early, even before the most careful examination reveals any tumor in the region of the kidney.

#### STRAIN OR PAINS IN THE BACK

*Rôle of the Lumbar Ligaments in Back Strain.*—Lowman,<sup>36</sup> writing of the iliolumbar ligaments of the spine, points out that these structures, aside from exerting a lateral, stabilizing effect, are also suspensory in function and act as a second line of defense in protecting the back from undue strain. If there is any failure of the sacro-iliac ligaments to support that joint, there must occur increased tension on all the other structures involved in supporting or stabilizing the spinal column. In the tilting forward of the pelvis on one side or the other, with a sudden twisting strain, the stress thrown on one of the iliolumbar ligaments is sufficient to produce a sprain, the symptoms being severe pain in the back and lateral deviation of the spine. In patients with hollow back and with the sacrum tilted forward, it can be readily seen that the sacrum bears less weight and these ligaments more because of their direct suspensory function. Evidence of the strain which these ligaments bear is to be found on roentgen-ray examination in the spur formation and calcification of these tissues.

*Traumatic Spondylolisthesis.*—Henry<sup>37</sup> reports three cases of traumatic spondylolisthesis, in which the patients dated their symptoms back to falls, several years previous, in which they landed in the sitting position. They returned to work within a few weeks after their accidents, but complained of pain originating at the time of injury. Henry states that the four cardinal signs of spondylolithesis are: (1) a prominent, vertically placed sacrum; (2) a palpable, visible hollow above the sac-

35. Alessandri, R.: *Policlinico* 33:273, 1926.

36. Lowman, C. L.: *Rôle of Iliolumbar Ligaments in Low Back Strains*, J. A. M. A. 87:1002 (Sept. 25) 1926.

37. Henry, M. O.: *Minnesota Med.* 9:376 (July) 1926.

recovery, and that the paralysis was not so profound or so extensive as in the untreated patients. The effect of spinal drainage on the acute symptoms was almost phenomenal, the symptoms disappearing for the most part a short time after the drainage and appearing only when the spinal pressure again rose above normal. The death rate in the series of patients who were treated was much smaller than that in the group of untreated patients. There was a glycosuria and hyperglycemia in a large percentage of the cases, thus substantiating the point made by several observers that this infection has some effect on the carbohydrate metabolism, the mechanism probably being an inflammation of the pituitary bodies. Diveley advises as the best treatment strict isolation, early and repeated spinal drainage to keep down abnormal pressure, and serum, either human or the immunized horse serum of Rosenow, given immediately after the spinal drainage, either intravenously or intramuscularly, depending on the severity of the symptoms.

#### SYPHILIS OF THE BONE

Dillingham and McCafferty<sup>13</sup> describe three cases demonstrating various phases of syphilis of the bone. One patient showed an early syphilitic periostitis. The second presented a syphilitic osteomyelitis of the cortical bone and a thickening of the periosteum with destruction of the soft parts overlying the clavicle. The third was one of extensive osteomyelitis, with thickening of the cortex and a definite periostitis with evidence of sinus formation and sequestrum.

#### PYOGENIC INFECTIONS

*Acute Hematogenous Osteomyelitis.*—Krasnobaew,<sup>14</sup> in discussing the subject of acute osteomyelitis, said that to him the importance of the problem arose from the great number of patients whom he had had to treat in his service during the twenty-one years from 1904 to 1925. The total number of cases was about 600, of which 428 were acute. From a careful study of the cases and of his results, he arrives at the following conclusions:

1. It is of special importance to consider the general condition of the patient, to take account of his vitality, and to have the greatest care for the tissues involved.
2. In the severe cases of acute osteomyelitis it is necessary to avoid, in the first stage of its evolution, all operations requiring general anesthesia.
3. Too radical treatment in the first stage of acute osteomyelitis is not only useless, but dangerous.
4. In the first septic period of osteomyelitis it is necessary to refrain from doing more than opening the abscess as early as possible by incisions reaching to the

13. Dillingham, F. H., and McCafferty, L. K.: *Am. J. Syph.* **10**:373 (July) 1926.

14. Krasnobaew, T.: *Chir. d. org. di movimento* **10**:537, 1926.

rum; (3) a sharp lordosis of the lower lumbar spine, and (4) limitation of extension in the lumbar spine. In all three of Henry's cases a fusion operation was performed on the spine. All the patients made a good recovery, and get along well at present, although they must avoid heavy lifting, bending and stooping.

*Bone Graft for Sacro-Iliac Fixation.*—Verrall<sup>38</sup> describes a new method for fixation of the sacro-iliac joint by means of a tibial bone graft. The graft is driven through drill holes in the posterior iliac spines and crosses transversely at the back of the sacrum, its middle portion coming in contact with the base of the second sacral spinous process and lying under the erector spinae muscles. The author has performed the operation in four cases, with satisfactory results. The first two patients were treated on plaster beds for five and three months, respectively. In the third case a spinal frame was used for the after-treatment, and in the last case no splint was used at all.

[ED. NOTE.—The operation appears less sound from the mechanical and physiologic standpoint than other operations now in use.]

#### MISCELLANEOUS

*Osteomyelitis Variolosa.*—The occurrence of lesions of the bone in smallpox has been pointed out from time to time by various writers; but such lesions have been observed heretofore only in the late stages. It has remained for Huenekens and Rigler<sup>39</sup> to record the changes in the acute period. They report the case of a child ill with smallpox who also presented a picture of acute polyarticular arthritis. The joint symptoms in the upper extremities developed shortly after the appearance of the eruption, and the involvement of the other joints followed rapidly. Roentgen-ray examination revealed widespread destructive processes located at the epiphyseal lines of the long bones and in the first cervical vertebra, which dislocated spontaneously. The acute condition in the bones continued for two months after the eruption had disappeared and was accompanied by fever and leukocytosis. Repair finally occurred with almost complete recovery except for the unreduced dislocation of the neck. The rapidity of the onset, the symmetrical, widespread dissemination and involvement of a vertebra, together with absence of suppuration, all coincide with Chiari's observations. The selective nature of the process, the lesions being confined to the region of growth in the bone, is in accordance with the ideas of Musgrave and Sison, based on their observation of the late deformities.

38. Verrall, P. J.: *J. Bone & Joint Surg.* 8:491 (July) 1926.

39. Huenekens, E. J., and Rigler, L. G.: *Osteomyelitis Variolosa, Acute Stage*, *J. A. M. A.* 87:295 (July 31) 1926.

bone. 5. Subsequently, the treatment of the inflammation requires all attention. 6. Gauze packs and tampons should not be used. Drainage tubes should be rarely used and only for a short time. 7. In cases of osteomyelitis of the diaphysis, involvement of the joint frequently develops from lack of proper care of the wound. 8. If the wounds are well treated, amputation or resection is rarely necessary. 9. At the end of the septic period, without waiting for the formation of an involucrum, sequestrectomy should be performed and all the necrotic parts removed. The wound should be sutured. 10. Motion is especially dangerous when osteomyelitis of an epiphysis is accompanied by suppurative arthritis. 11. In cases of epiphyseal osteomyelitis of infants, especially when the suppuration has not yet invaded the joint, one should use repeated aspirations by means of a syringe. 12. In the severe cases in infants, when the aspirations are insufficient; in adolescents, and also in cases in which the pus has invaded the capsule, incisions and arthrotomies are necessary. The incisions need not be large. In these cases, also, gauze packs and tampons are to be avoided. 13. The necessity of resection occurs only in cases of epiphyseal osteomyelitis of the hip, and even here it is necessary to resect only in rare cases in which there is necrosis of the epiphysis with separation of the epiphysis from the diaphysis.

*Acute Suppurative Arthritis.*—Caldwell,<sup>15</sup> in discussing the treatment of well established suppurative arthritis, gives the following advice. Aspiration, with or without the injection of antiseptics, is inadequate. Arthrotomy by one or more incisions, adequately large, is indicated as soon as diagnosis is made. Intracapsular drains are dangerous and superfluous. Immediate, active mobilization following arthrotomy appears to be unnecessary, to say the least of it. Since the results of the so-called Willem's method are certainly no better than, if as good as, those in which arthrotomy has been followed by fixation, it would seem wiser to abandon it for the simpler, more logical, more truly orthopedic and surgical procedure of arthrotomy followed by fixation.

[ED. NOTE.—On the basis of previously published reports and our own experience, we feel that there is a place for repeated aspiration as a method of treatment in certain mild cases of suppurative arthritis. Nor do we agree with Caldwell that complete fixation is desirable as a routine measure. We believe that in certain cases mobilization should be encouraged as early and as actively as possible.]

#### DISEASES DUE TO NUTRITIONAL DISTURBANCES

*Rickets.*—Cozzolino<sup>16</sup> reports a case of congenital myxedema and discusses the possibility of this disease coexisting with rickets. He states that most writers admit that the diseases which interfere with or inhibit

15. Caldwell, G. A.: *South. M. J.* 19:637 (Aug.) 1926.

16. Cozzolino, O.: *Pediatrics* 34:761, 1925.

*Melitococcus Spondylitis*.—Roger <sup>40</sup> of Marseilles calls attention to the frequent occurrence of spondylitis in Malta fever. He reports vertebral lesions of a characteristic type in about 30 per cent of the cases.

*Chronic Osteitis of Semilunar Bone (Kienböck's Disease)*.—Henderson <sup>41</sup> reports two cases of osteitis of the semilunar bone, or Kienböck's disease. The etiology of this condition is generally thought to be traumatic, either a definite injury or repeated trauma incidental to occupation. Kienböck's syndrome is characterized by three stages: (1) the acute, lasting possibly only a few hours, coming on immediately after the injury, rarely lasting more than a few days, and generally not more than a few weeks; (2) the period of freedom from pain and disability, sometimes lasting as long as two months; (3) the period of actual disease, in which the osteitis definitely assumes form and persists with symptoms, perhaps for years. Kümmell's disease is the nearest analogy. Roentgenograms immediately after the injury do not show abnormalities, but later show varying degrees of osteitis. The author advised against operation in his cases, treating the patients by splinting.

*Spontaneous Dislocation of the Biceps Tendon*.—Meyer,<sup>42</sup> an anatomist, has observed in the dissecting room four cases of complete dislocation of the tendon of the long head of the biceps brachii, three in men, one in a woman, out of 286 cadavers, or 1.25 per cent. The tendon was not adherent and was wholly preserved, even when the entire superior portion of the articular capsule was completely destroyed. All the subjects were elderly, and there were well marked senile changes in the bone and joint capsule. In regard to the genesis of this dislocation, Meyer thinks it can be produced only after destruction of the superior portion of the articular capsule and then only in the position of marked abduction and lateral rotation, facilitated perhaps by flexion of the forearm in the supinated position. Such conditions would produce a maximum of relaxation of the tendon and permit it to be carried forward over the lesser tuberosity. Once dislocated it would probably always remain, especially if continued attrition in the region of the tuberosities led to bony proliferation and obliteration of the intertubercular sulcus.

*Spontaneous Dislocation of the Hip*.—Jones <sup>43</sup> has studied a series of twenty-seven spontaneous or pathologic dislocations of the hip. These are classified as follows: (1) dislocation from muscular paralysis; anterior poliomyelitis, six cases; spastic paraplegia, one case; (2) dislocation from acute arthritis; septic arthritis, three cases; pneumococcal arthritis, three cases; arthritis of exanthemas, two cases; pyemic arthritis, one case;

40. Roger, H.: Presse méd. 34:929 (July 24) 1926.

41. Henderson, M. S.: J. Bone & Joint Surg. 8:504 (July) 1926.

42. Meyer, A. W.: Spontaneous Dislocation of Tendon of Long Head of Biceps Brachii, Arch. Surg. 13:109 (July) 1926.

43. Jones, R. W.: Brit. J. Surg. 14:36 (July) 1926.

the regular growth of the nursing child prevent the development of rickets. There are a few authors who refuse to accept this. Cozzolino does not believe that any proof of the impossibility of association of myxedema and rickets has yet been brought forward, but care must be exercised in making such a diagnosis if the sign on which the diagnosis of rickets is based is craniotabes. An error may creep in here, as it has not been absolutely proved that craniotabes is pathognomonic of rickets.

Experiments made by Maslow, Shelling and Kramer<sup>17</sup> demonstrate that antirachitic properties can be imparted to orange juice by irradiation with the quartz mercury vapor lamp. Healing may be demonstrated as early as five days after feeding irradiated orange juice to rachitic rats, and is almost complete at the end of fifteen days.

*Comparison of Antirachitic Potency of Irradiated Cod Liver Oils.*—A medicinal cod liver oil of known origin, known chemical and physical characteristics, and of vitamin A potency, was irradiated by Wyman and his group of co-workers<sup>18</sup> under carefully controlled conditions for periods varying from one-half to two hours. The antirachitic potency of the original oil and of the irradiated oils was studied to determine to what extent the antirachitic activity of the original oil was enhanced by irradiation with the ultraviolet ray. The results obtained indicate that there was little if any difference in the antirachitic potency of the original oil and that which had been irradiated.

*Osteitis Fibrosa Generalisata.*—Mandl,<sup>19</sup> after discussing the possibility of relationship between the parathyroid bodies and generalized osteitis fibrosa, reports the case of a man, aged 39, who was suffering from an advanced, severe form of that disease. Examination of the urine showed a marked increase above normal in the quantity of calcium that was being excreted. Excision of a small tumor of one of the epithelial bodies resulted in marked improvement. The excessive elimination of calcium salts in the urine was stopped. There was improvement, both subjective and objective, with increase in weight, and the roentgen-ray examination showed a marked increase in the lime content of the bone.

*Hypertrophic Osteo-Arthropathy.*—Ramond and Bascourret<sup>20</sup> discuss a case of hypertrophic osteo-arthropathy of Pierre Marie. The patient, a policeman, aged 26, complained of an abnormal and progressive

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17. Maslow, H. L.; Shelling, D. H., and Kramer, P.: Bull. Johns Hopkins Hosp. July, 1926, p. 56.

18. Wyman, E. T.; Holmes, A. D.; Smith, L. W.; Stockberger, D. C., and Pigott, M. G.: Boston M. & S. J. 195:525, 1926.

19. Mandl, F.: Zentralbl. f. Chir. 53:260, 1926.

20. Ramond, L., and Bascourret: Bull. et mém. Soc. méd. d. hôp. de Paris 50:1015, 1926.



arthritis of doubtful origin, three cases; acute tuberculous arthritis, two cases; (3) dislocation from chronic arthritis, none; (4) subluxation from chronic arthritis: tuberculous arthritis, two cases; osteo-arthritis, three cases; hemophilia, one case. The author believes that the underlying pathology is essentially the same in all cases, a muscular derangement resulting in extreme flexion and adduction. This is unquestionably true in the paralytic cases; in the arthritic cases the inflammatory process alone does not bring about dislocation unless accompanied by abductor and flexor spasm. The deformity must be one of both flexion and adduction to produce a dislocation; flexion alone or adduction alone may cause a subluxation, but never a complete dislocation. In chronic infections of the hip, complete dislocations do not occur, because the muscle spasm is not sufficiently severe. The condition can be prevented in both paralytic and arthritic patients by preventing adduction and flexion. Corrective measures, on the whole, are unsatisfactory, because the dislocation in so many cases is associated with other irreparable damage.

[ED. NOTE.—We are inclined to be more optimistic than Jones appears to be in respect to the value of corrective operations in spontaneous dislocations of the hip. In the paralytic patients the shelf operation, with suitable modification, affords a means of stabilization. In the tuberculous cases one must employ an ankylosing operation to obtain the same end. Dislocation resulting from septic infection constitutes the most difficult problem on account of the risk of a flare-up of an old septic process, but even here by means of carefully planned and executed operations it is often possible to obtain an ankylosis.]

(To be Continued)

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#### CORRECTION

In the article by Dr. Deryl Hart, entitled, "Intracystic Papillomatous Tumors of the Breast, Benign and Malignant: Analysis of One Hundred and Twenty-Four Cases (ARCH. SURG. 14:793 [April] 1927), some of the legends, beginning with figure 6, are incorrectly placed. The legend under figure 6 should be under figure 18, and each of those following should appear under the preceding illustration, i. e.: the legend under figure 7 should be under figure 6; that under figure 8 should be under figure 7, and so on.

enlargement of the hands and feet, with slight pain and crepitation in the knees, ankles and wrists, and a sense of general fatigue. The condition had had its onset four years previously. The examination showed osteo-articular deformities localized at the extremities, characteristic appearance of the fingers with incurvation of the nails. The picture on roentgen-ray examination was typical. In discussing the origin, which is chiefly from pulmonary diseases, Léri states that small chronic lesions of sclerosing tuberculosis are able to give the syndrome.

*Dwarfism with Pluriglandular Syndrome.*—Bénard, Hillemond and Laporte<sup>21</sup> present a case of dwarfism with pluriglandular syndrome. The striking feature was the small stature with remarkable shortness of the extremities, which led them to suggest the term "nanisme acromicrique" in contrast to "gigantisme acromégalique." The patient was a girl, aged 17, with a complexity of symptoms of myxedema, with pigmentation and sclerodactylia. The condition was different from the micromelia of Galliaud and Levy, the dyschondroplasia of Ollier and the pituitary dwarfism described by Erdheim.

#### DISTURBANCES OF GROWTH

*Osteochondritis of the Epiphyses.*—Christie,<sup>22</sup> discussing the whole subject of epiphyseal osteochondritis, states that there is little doubt that the etiologic factors and pathologic changes are similar in Legg's disease, Schlatter's disease, Koehler's disease and vertebral epiphysitis. The same disease also occurs in the epiphyses of the os calcis and of the olecranon. There is also fairly good evidence that the osteochondritis dissecans of König and the rare condition known as malacia of the carpal semilunar bone belong in the same category. Regarding the etiology of epiphyseal osteochondritis, Christie states that there is no agreement, except that it is definitely known that the disease is not tuberculous, rachitic or syphilitic. There is a little evidence to support an infectious theory, but the cases in which operation has been performed and in which a possible causative organism has been isolated, are so few that they may be explained on the grounds of coincidence or of accidental contamination. The theory of an endocrine origin is a pure assumption with no reliable evidence to support it. A history of trauma is present in some of the cases, but not in a sufficient proportion to make it appear to be the ultimate cause. The supposition has been advanced that the condition is primarily due to some developmental anomaly or constitutional disturbance which eventually results in poor nourishment of the epiphysis at the time of its more rapid development. It is worthy of note that each lesion is associated with a definite age period, and that the period is the

21. Bénard, R.: Bull. et mém. Soc. méd. d. hôp. de Paris 50:967, 1926.

22. Christie, A. C.: Osteochondritis or Epiphysitis; Review, J. A. M. A. 87:291 (July 31) 1926.

## HALLUX VALGUS

FINAL RESULTS IN TWO HUNDRED OPERATIONS \*

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During the period covered in this report, from 1917 to 1924, inclusive, about 300 operations for hallux valgus were performed at the New York Orthopedic Dispensary and Hospital. I have been able to review the results in 200 of these operations performed on 108 patients. The statistics in most instances refer to individual feet and not to the patient. The average length of time which elapsed between operation and final examination was twenty-eight months.

The work was done by twenty-five different surgeons, fifteen of whom were on the resident staff and ten on the visiting staff. A little more than half of the operations were performed by the members of the visiting staff.

### THE PATIENTS

Ninety per cent of the patients were women, and 80 per cent were between the ages of 20 and 60. There were seven patients under 20 and three over 60 years of age.

In those patients who gave reasons for submitting to operation, pain was found to be the sole cause in 50 per cent; 23 per cent desired operative intervention simply because of deformity, and the remainder because of both pain and deformity.

The average duration of the condition was said to be about six years, but this is inaccurate. The question might have been interpreted as relating to either symptoms or deformity. One of the patients had had bunions for thirty-five years and five had had them more than twenty years.

Sixty-one of the patients had not had previous treatment, and of the remaining forty-seven, the majority had merely worn broad shoes, arch supports, and other devices, and had been under the care of a chiropodist. It is safe to assume that if their treatment had been satisfactory they would not have sought operative intervention.

### PREOPERATIVE CONDITION OF FEET

*Limited Dorsal Flexion and Pronation.*—Since 93 per cent of the patients showed dorsal flexion of the feet limited to 90 degrees or more,

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one in which the affected nucleus of the bone is undergoing its most active development. The opinion of the majority of investigators inclines to the idea that the disease is due to long continued or occasionally acute trauma, resulting in interference with the circulation and in subsequent necrosis involving both the bone and the cartilage of the epiphysis.

*Coxa Plana.*—Valle and Verbrugge<sup>23</sup> report some observations on the rôle of heredity in coxa plana and kindred conditions of the hip. Their studies lead them to conclude that both heredity and age are important factors. One may inherit a predisposition to these conditions, accompanied or not by actual malformation. There is a potentiality of disease which under the influence of trauma, of infections, of nutritive disturbances or of endocrine disorders may produce in the period of childhood osteochondritis or coxa vara; in youth, coxa vara of adolescence, and in adult life, arthritis deformans.

*Case of Legg-Perthes' Disease.*—Kidner<sup>24</sup> reports a case of what he regards as Legg-Perthes' disease. The history began with weakness of the left hip, observed by a mother in an infant. The child walked late, and gradually developed a limp; there was only slight pain. When first seen, at the age of 8 years, there was 1 inch (2.5 cm.) shortening, and the motions were limited to 15 degrees in all directions. Roentgen-ray examination showed spina bifida occulta of the fifth lumbar, deformity of the head and neck of the femur and of the acetabulum, characteristic of Legg-Perthes' disease. Neurologic examination showed complete anesthesia of the anterior two thirds of the thigh and lower leg, hyperesthesia of the posterior third. A biopsy was performed, and the cartilage appeared smooth and apparently normal. A section of the head was examined by Dr. W. B. Phemister, who found both degenerative and reparative changes, but no evidence of inflammation. He regarded the process as a circulatory disturbance and considered it a case of Legg-Perthes' disease, despite the early age of onset.

[ED. NOTE.—We would have some hesitation in calling this Legg-Perthes' disease in view of the history and of the neurologic disturbance, nor do we believe that the pathologic picture of Legg-Perthes' disease has yet been sufficiently established to permit the observations on study of the specimen to be adduced as proof. Is it not possible that a neurotrophic process affecting the hip might give the same appearance?]

*Apophysitis of the Os Calcis.*—O'Ferrall<sup>25</sup> believes that both trauma and infection play a part in the etiology of apophysitis of the os calcis. Many cases are undoubtedly not recognized, and recover under the treat-

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23. Valle and Verbrugge: *Chir. d. org. di movimento* 10:364, 1926.

24. Kidner, F. C.: *J. Bone & Joint Surg.* 8:565 (July) 1926.

25. O'Ferrall, J. P.: *South. M. J.* 19:549 (July) 1926.

it was thought best to make an arbitrary division between a definitely muscle-bound foot and a relatively normal foot at 95 degrees. Sixty-seven per cent of the patients presented muscle-bound feet, and 87 per cent presented varying degrees of pronation. The relation which limited dorsal flexion and pronation bear to hallux valgus is interesting. My observations tend to the conclusion that hallux valgus rarely if ever occurs in an otherwise normal foot.

*Hallux Valgus.*—The deformity due to hallux valgus was designated as slight at 20 degrees or less, moderate at 20 to 35 degrees, and severe over 35 degrees. The cases were distributed as follows: forty-seven cases, or 23 per cent, slight; seventy-five cases, or 37.5 per cent, moderate; seventy-eight cases, or 39 per cent, severe.

The maximum deformity recorded was 90 degrees in a patient 50 years of age. Another patient, 19 years old, showed a deformity of 75 degrees.

*Anterior or Transverse Arch.*—The anterior arch was well maintained in only 18 cases and impaired in varying degrees in the remaining 182, slightly in 39, moderately in 42 and severely in 101 cases. Callosities were present on the ball of the foot in proportion to the impairment of the arch.

This impairment of the anterior arch is due to the separation of the first and second metatarsal bones distally, a condition which is part of the deformity in all except the simplest cases. This separation may be due to the presence of an extra bony element, the intermetatarsium, which may exist as a small separate bone or be found fused with the medial cuneiform or base of the first or second metatarsal. Dwight<sup>1</sup> found it most commonly fused with the medial cuneiform so that it presented an elongation of the outer distal angle of that bone. It is conceivable that an extra bone placed at the outer side of this metatarsocuneiform joint, attached either to the metatarsal or cuneiform bone might cause a medial deviation of the first metatarsal and consequent widening of the first metatarsal space. This region is not distinct in the roentgenogram owing to overlapping of joint lines (fig. 1).

*Arthritis.*—Fifty-five of these patients presented evidence of active symptomatic arthritis in the joint of the great toe before operation, such as crepitation, swelling and other symptoms. Eight cases were classified as severe and the others as mild or moderate. This condition has considerable bearing on the end-results and will be dealt with more fully later.

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1. Dwight, Thomas: Variations of the Bones of the Hands and Feet, Philadelphia, J. B. Lippincott Company, 1907.

ment of simple sprain. His conclusions are as follows: Apophysitis of the os calcis is most common in growing boys during the period of their greatest growth activity. The condition clinically is usually unilateral, but by roentgen-ray examination the epiphysis on both sides is often found to be involved. Close questioning may reveal that bilateral symptoms have existed, one side being more affected than the other. Freedom from weight-bearing, fixation of the extremity in a plaster cast to lessen the pull of the Achilles tendon and the administration of cod liver oil usually relieve the condition promptly and permanently.

[ED. NOTE.—We are not at all convinced that it is necessary to employ plaster fixation in the treatment of this condition. The symptoms are usually mild and are promptly relieved by adhesive strapping and elevation of the heel. We have seen no bad results, even in those patients who have been totally untreated.]

*Symmetrical Disease of the Epiphyses of the Hand.*—Kloiber<sup>26</sup> describes a symmetrical disease of the middle joints of the third fingers of both hands which is accompanied by a slight disturbance of the function. Clinically, there is slight thickening, and the roentgen-ray examination shows a marked change in the epiphysis of the second phalanx. The epiphysis is diminished in length, but markedly increased in width. The epiphyseal line is irregular and thicker than normal. The articular gap is narrowed and in some places seems to have disappeared. The nucleus is split in two or three fragments. The disease closely resembles Koehler's disease of the metatarsal head, particularly in regard to the destruction of the epiphysis, the enlargement of the metaphysis and the slight disturbance of function.

*Significance of Accessory Tarsal Scaphoid.*—Zadek<sup>27</sup> discusses the significance of the accessory tarsal scaphoid in its relation to weak feet. He has operated on three such cases and found an abnormal insertion of the tibialis posticus, the tendon being entirely or mainly inserted into the scaphoid. This results in muscular imbalance and leads to weak feet. Such cases do not respond to supportive or exercise treatment. Good functional results are obtained by removal of the accessory scaphoid and of the prominent portion of the scaphoid if accompanied by astragalo-scaphoid arthrodesis.

#### ARTHRITIS

*Classification and Treatment of Chronic Arthritis.*—Cecil and Archer.<sup>28</sup> after four years' experience with chronic arthritis in the Cor-

26. Kloiber: Fortschr. a. d. Geb. d. Roentgenstrahlen 34, no. 4, 1926.

27. Zadek, I.: J. Bone & Joint Surg. 8:618 (July) 1926.

28. Cecil, Russell L., and Archer, Benjamin H.: Classification and Treatment of Chronic Arthritis. J. A. M. A. 87:741 (Sept. 4) 1926.

*Exostosis and Bursa.*—Since 1922 records have been kept of the size of the exostosis which is usually present over the medial side of the first metatarsal bone. In the eighty cases reported, the exostosis was described as large in thirty-three, moderate in seventeen and as small in three. Removal of an exostosis at operation in twenty cases indicated that it was a factor in the deformity and pain, although this was not mentioned in the case reports.

Over the exostosis bursae of varying size, frequently inflamed, were noted. The pain attendant on an inflamed bursa over the bunion is unquestionably the impelling factor which causes a patient to seek relief.

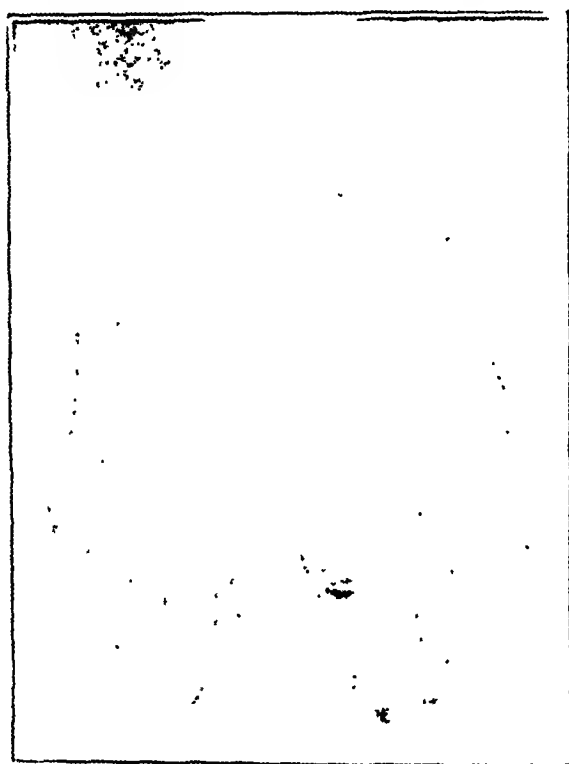


Fig. 1.—Both feet have been subjected to the same footwear but the right shows a marked hallux valgus, while the left shows a slight deformity. It will be noted that the deviation of the right first metatarsal bone is marked at the base and is caused by a prominent projecting ridge on the outer distal angle of the medial cuneiform bone, a fused intermetatarsum.

*Roentgenogram.*—Recently it has been our plan to secure a pre-operative roentgenogram of the feet in order to see the actual size of the metatarsal head and determine in a measure the proper procedure. In a number of the later cases in the series these roentgenograms have been made, and they have been of value. A postoperative roentgenogram has also been made in order to check up the operative procedure (Figs. 2 and 3).

nell Clinic, are convinced that this disease occurs in two distinct and fundamentally different clinical forms. They prefer the classification of Nichols and Richardson, feeling that the division into the two groups, proliferative and degenerative, rests on definite pathologic and probably etiologic grounds. They feel that the proliferative form is almost certainly infectious in origin and that the degenerative type is noninfectious. They are not able to exclude the possibility of some toxic factor playing a part in the causation of degenerative arthritis. Largely on the basis of clinical manifestations, they differentiate three subdivisions of each group:

I. Proliferative Type Arthritis: (*a*) chronic infectious arthritis; (*b*) specific arthritis; (*c*) true arthritis deformans, a chronic progressive polyarthritis of unknown origin. II. Degenerative Type Arthritis: (*a*) arthritis of the menopause; (*b*) degenerative monarticular arthritis (*morbus coxae senilis*); (*c*) senile arthritis. In the proliferative type different infectious agents are probably responsible for the different clinical manifestations. The three subdivisions of degenerative arthritis are largely a matter of clinical convenience, though here, again, a variety of etiologic factors may play a part. It seems probable, for example, that arthritis of the menopause is dependent on some endocrine disturbance. In a study of 612 cases of chronic arthritis, approximately two thirds (68 per cent) were of the proliferative type and one third (30 per cent) were of the degenerative type. Proliferative arthritis occurs most frequently in young persons; degenerative arthritis is more often seen in the middle-aged and elderly. The commonest form of proliferative arthritis is associated with focal infection about the teeth or tonsils. The commonest variety of degenerative arthritis is the arthritis of the menopause. The proliferative arthritis is presumably an infectious process. Degenerative arthritis does not appear to be of infectious origin. It appears more likely that it is, as its name implies, a degenerative process analogous to arteriosclerosis and to the other degenerative changes that attack various organs in old age. The essential feature in the treatment of proliferative arthritis is the removal of all foci of infection. In degenerative arthritis the treatment should be directed chiefly toward accelerating metabolism by means of the iodides, physiotherapy and other appropriate measures. Many of these patients are improved by a low caloric diet.

[ED. NOTE.—We think it is of interest to note that the conclusions of Cecil and Archer are in line with those of nearly all observers who have had the opportunity of making an intensive study of chronic arthritis. There are two distinctive main types of arthritis in the opinion of most authorities, and the subdivisions made by Cecil and Archer may be recognized under other names used by different writers.]





A



B

Fig. 2.—*A*, preoperative roentgenograms of a case in which the exostosis was widely excised, together with the exostosis on the proximal end of the phalanx; *B*, postoperative condition.



A



B

Fig. 3.—*A*, preoperative roentgenogram of a case in which the exostosis on the metatarsal head was widely excised. The exostosis on the proximal end of the phalanx was left, and caused subsequent annoyance; *B*, postoperative condition.

*Diet in Treatment of Chronic Arthritis.*—Pemberton<sup>29</sup> says that it is common knowledge that even in health a great intake of food may induce hebetude and lethargy probably through an influence on the flow of the blood, and there is reason to believe that it is through an influence on the flow of the blood that a curtailment of diet exerts part of its effect in arthritis. In view of the undoubted benefit of measures which improve the flow of the blood and hasten metabolism, such as exercise, massage and external heat, it seems likely that at least part of the influence of a reduced diet results from placing a lessened demand on the machinery of exogenous metabolism, especially in the muscles. Pemberton says that the chief considerations in dietetics are: first, to reduce the total caloric intake to suit the individual case—in general, to about 30 Kg. of body weight according to the usually accepted approximate requirements for rest; and second, in diets of relatively high caloric value, to redistribute the foodstuffs so that the proportion of calories is larger from fats than in the usual dietary and less from carbohydrates. Pemberton feels that diet constitutes the best method of meeting the therapeutic indications in chronic arthritis.

*Vaccine Therapy and Serologic Diagnosis in Arthritis.*—Burbank<sup>30</sup> reviews the history of vaccine therapy in arthritis and outlines his own method of procedure. The isolation and identification of the organisms is the most difficult task, and for this process careful serologic methods of study are all-important. Vaccine treatment, when properly prepared, controlled and administered, represents, in his opinion, the most potent method of attacking this disease. To treat a patient adequately it is also important to see that the hygiene and environment are rendered as favorable as possible. He believes that favorable results may be obtained in practically all patients whose serologic reactions show favorable complementary values, if they have not undrained infectious foci, are not suffering from any debilitating disease, and have the patience to continue the treatment over considerable periods.

*Rôle of Dysentery Bacillus in Arthritis Deformans.*—Clifford<sup>31</sup> reports his studies of seven cases of arthritis deformans of type I, in four of which there was evidence either of an active or of a partial infection with *Bacillus dysenteriae* of Flexner. He feels that dysentery should be considered as an etiologic factor in this form of arthritis and ruled out only after bacteriologic studies and agglutination reactions, using a complete series of antigens. He does not feel that his observations cover a series of cases large enough to permit any more definite conclusions.

29. Pemberton, R.: New York State J. M. 26:658 (Aug. 1) 1926.

30. Burbank, R.: J. Bone & Joint Surg. 8:657 (July) 1926.

31. Clifford, S. H.: Rôle of Dysentery Bacillus in Arthritis Deformans, Am. J. Dis. Child. 32:72 (July) 1926.

## OPERATION

*Operative Procedures.*—The operative procedures fall into five groups: (1) resection of the metatarsal head with removal of the exostosis (Mayo operation); (2) simple excision of the exostoses without interfering with the joint; (3) resection of the proximal end of the first phalanx and removal of the exostosis on the metatarsal head (Keller operation); (4) excision of the exostosis on the metatarsal head, division of the lateral ligaments of the capsule and the adductor muscles and realinement of the phalanx and metatarsal bones by means of a wedge-shaped flap fashioned from the medial ligament (Silver operation), and (5) wedge-shaped osteotomy of the metatarsal or proximal phalanx to correct the deformity.

The cases were distributed among these groups as follows: Resection of metatarsal head, 118; excision of exostosis, 38; resection of proximal end of phalanx, 22; excision of exostosis with plastic repair, 15; cuneiform osteotomy, 7.

As an additional operative procedure, the extensor hallucis longus tendon was lengthened in eighty-six cases and divided in four cases. This tendon was therefore considered an important deforming factor in 45 per cent of the entire series. This lengthening is usually part of the operative procedure at the present time.

The achilles tendon was lengthened in thirty-four of the cases in which the feet were severely muscle-bound. In nine cases, the exostosis on the fifth metatarsal head was excised for *varus minimi digiti*.

*Days in Hospital.*—The number of days to be spent in bed is important to the patient and to the hospital, and one should be able to give a patient some idea of the length of his stay in the hospital. Before 1922 the average number of days in bed for all patients was eighteen; it has since been reduced to fourteen and one-half days, a considerable saving.

The convalescent periods for the operative procedures in these cases compared as follows: Resection of the metatarsal head, seventeen days; excision of exostosis, twelve and one-half days; resection of proximal end of phalanx, twenty-one days; plastic repair, sixteen days; osteotomy, fourteen days.

My experience tends to show that a patient who can devote about four weeks to the operation and the immediate postoperative treatment is likely to shorten the entire convalescent period.

## POSTOPERATIVE COURSE

*Immediate Postoperative Complications.*—There were fifteen cases of infection, in eleven of which the end-results were good or excellent; all of these were resections. None of the four in which there were poor or fair results were resections.

*Rheumatic Nodules.*—Coates and Coombs<sup>32</sup> have made a study of rheumatic nodules. They describe the tiny granules which are found in the subcutaneous tissue of the rheumatic child and discuss their significance. The constitution of rheumatic nodules obtained from patients with rheumatoid arthritis, Still's disease and endocarditis lenta is described. They are shown to be histologically identical with those found in orthodox rheumatic infection.

#### TUMORS OF BONE

*Lesions of Bone.*—Bloodgood<sup>33</sup> gives a brief review of different types of lesions of bone based on a study of about 1,000 cases. He states that there is a small but increasing number of cases of sarcoma of the bone in which the patients have remained well for five years or more after amputation, cases which have been accepted under Codman's valuable registry of bone tumors. The fact that the diagnosis is being made at an earlier period is the one explanation of these better results. The improvement in diagnostic ability is undoubtedly due to the interest stimulated by the registry. Sarcoma is greatly on the increase. Bloodgood feels that many patients formerly died at home without record. Now practically all reach some clinic, where a roentgen-ray examination is made. He says that the greatest increase has occurred in certain types of lesions of the bone: healed bone cysts, Paget's disease, sclerosing nonsuppurating osteomyelitis, and a form of destructive osteomyelitis, often multiple, but when occurring as a single lesion difficult to differentiate from sarcoma and multiple exostoses. Syphilitic lesions of bone are decreasing. The number of amputations for giant cell tumor has decreased far beyond expectations. A limb is seldom amputated unnecessarily. Radiation is being given a fair trial, and the dangerous biopsy is becoming less frequent.

*Operability of Bone Tumors.*—Meyerding<sup>34</sup> says that the operability of a bone tumor depends on its local and general characteristics. Whether malignant or benign, the type, size or situation may prohibit surgical removal. In certain benign cases if the growth is accessible, operation may offer hope of a permanent cure. In doubtful cases, operation affords the means of definite diagnosis, and in case of malignancy removal offers palliative relief, if not more. The age and sex of the patient, size and origin of the tumor, its penetration through or invasion of periosteal tissue, its proximity to important structures, the danger of fracture and the general physical condition of the patient are all factors which must be taken into account in determining the operability.

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32. Coates, V., and Coombs, C. F.: Arch. Dis. Child. 1:183 (Aug.) 1926.

33. Bloodgood, J. C.: South. M. J. 19:541 (July) 1926.

34. Meyerding, H. W.: Radiology 7:29 (July) 1926.

The presence of infection did not seem to influence the end-result per se. It may have made poor results worse.

*Postoperative Treatment.*—The majority of the patients were treated by massage and exercise for two or three months. In twelve cases, postoperative treatment was not instituted, and in many of these the most brilliant results were obtained. In contrast to this, several patients who came to the dispensary over a period varying from a year to eighteen months after operation achieved a poor final result, which shows conclusively that a poor result cannot be improved by massage. Too active massage and manipulation in some cases may be a definite cause of a poor end-result.

*Definition of End-Results.*—Before proceeding to the study of the end-results, it may be well to define the four groups by which the varying degrees of success or failure in operations for hallux valgus are recorded. In each group the cosmetic and functional end-results are noted.

The cosmetic result is determined by the degree of hallux valgus, the general appearance of the toe and its alinement with the foot, the preoperative condition being taken into consideration.

The functional result is almost invariably of much greater importance to the patient than the cosmetic result. It expresses the mobility of the toe, the amount of control which the patient has over it and its general usefulness and efficiency in the propulsion of the body in walking. The absence or presence of pain is another important factor in determining this end-result.

An excellent functional result should have roughly the following features: over 35 degrees of extension and about 20 degrees of flexion of the toe. Control of the toe should be free. A good result should have an extension of 20 to 35 degrees and a flexion of 10 to 20 degrees. Control of the toe should be almost free. A fair result should have an extension of 10 to 20 degrees, flexion less than 10 degrees, and control of the toe is limited. A poor result has less than 10 degrees of extension, flexion and control of the toe are almost lacking.

In judging the end-result, the importance of extension of the metatarsophalangeal joint cannot be overemphasized. Since all the "take-off" or final propulsion in walking takes place through this joint, a considerable degree of extension is necessary to an easy, painless gait.

It is possible to have an excellent cosmetic result in a stiff, useless and painful toe with a poor functional result.

When only one unqualified result is expressed, I have attempted to average cosmetic and functional results.

around the femur. Microscopic examination was made by Dr. J. Ewing, who reported malignant spindle and giant cell osteogenic sarcoma; considerable production of osteoid tissue in the marrow regions; many areas of hemorrhage and some points of mucoid degeneration; some broad areas of hyaline material without cells. He stated that radium effects could be traced in the hemorrhages.



Fig. 55 (case 121 in table 7).—Two weeks later than figure 54.

mucoid degeneration, irregular calcification, and general hyperchromatism of the tumor cell nuclei.

The patient made a good recovery and the toxins were resumed, and kept up with occasional intervals of rest for six months. He has remained in excellent condition up to present time, six years later. This case is registered by the Bone Sarcoma Registry.

*CASE 27.—Periosteal round cell sarcoma of tibia treated with toxins and radium; patient well five years later; limb saved.*

A. K., a boy, aged 16 years, with a negative family history, had a fall in May, 1920, while playing basketball. Two months later he felt pain in the left knee, which gradually increased in severity. Three casts were applied; the first was worn for eight weeks; the second for six weeks, and the third for about eight weeks, or until his admission to the Hospital for Ruptured and Crippled, Feb. 2, 1921. The day after he entered an exploratory operation was performed by Dr. Percy Roberts, who removed by curet a mass situated at the head of the tibia on the posterior aspect. The microscopic diagnosis of Dr. F. M. Jeffries was round cell osteosarcoma. The mixed toxins were begun February 10, and continued in gradually increasing doses up to 10 minims. Examination, March 10, showed the wound healed, and the knee joint movable so that it could be flexed to a right angle without pain or resistance; the patient's general condition was excellent. Roentgen-ray examination, April 14, showed no extension of the tumor process. April 18, he was transferred to the Memorial Hospital. On his admission, a roentgen-ray examination was made by Dr. Herendeen, who reported as follows: "Plate of chest is negative for metastases. In the internal condyle or tuberosity of the left tibia there is a large area of rarefaction, bone absorption or destruction; the process has not definitely broken through the cortex."

It was decided to supplement the toxins with radium, and from May 7, 1921, to November 29, the patient received over various aspects of the knee radium packs applied at 6 cm., a total of 96,554 millicurie hours.

The roentgen-ray report by Dr. R. E. Herendeen, July 28, 1922, was: "Plate of chest reveals evidence of an infiltration, probably tuberculous. Plate of tibia reveals evidence of further calcification and favorable progress."

The roentgen-ray report, June 28, 1924, was: "Plate of chest reveals no evidence of sarcoma metastases. Extensive pulmonary tuberculosis present. Evidence of some improvement in process in upper end of tibia."

Physical examination, June 25, 1924, showed the motion of the knee to be normal; the patient had been in a home for tuberculous patients for a year. Examination in May, 1925, showed the local condition to be normal, and the lung condition to be slightly improved. The lung condition soon become worse, and the patient's general condition rapidly declined; he died in November, 1925. The microscopic diagnosis of Ewing was osteogenic sarcoma. The case is registered by the Bone Sarcoma Registry.

*CASE 28 (Dr. Douglas Quick).—Periosteal sarcoma of humerus treated with radium for seven months; amputation; patient well more than three years later.*

L. O., a woman, aged 31, in November, 1920, noticed a small swelling on the right elbow; this slowly increased in size. In March, 1921, it began to increase more rapidly and was very painful; a biopsy was performed at this time by Dr. Charles A. Elsberg. The patient was admitted to the Memorial Hospital, Dr. Quick's service, April 21, at which time examination showed a large tumor just above the elbow 15 inches (37.5 cm.) in circumference. Roentgen-ray examination showed apparently no bony involvement, and an apparently intact periosteal line. The patient was treated by Dr. Quick with radium in the form of packs; from April to November, 1921, she received a total of 85,000 millicurie hours. The tumor steadily increased in size in spite of treatment and an amputation was performed by Dr. Quick, November 16. The microscopic diagnosis of Ewing was large spindle cell sarcoma, apparently of periosteal origin. This patient moved west within a year after amputation and only indirect information as to her condition has been received.

## END-RESULTS IN AUTHOR'S SERIES

The end-results in this series may be subjected to criticism from two standpoints: the small number of cases in some of the groups and the large number of surgeons of varying experience who performed the operations. A record of 76.5 per cent of good or excellent results therefore seems creditable.

*The Great Toe.*—The deformity was improved most by osteotomy which resulted in 30 degrees of correction, and least by simple excision of the exostosis which gave 5 degrees of correction. Twenty degrees correction was obtained in both types of resection, and only 8 degrees in the plastic operation (table 4).

Resection of the metatarsal head allowed an average extension of over 40 degrees, while the osteotomy resulted in an extension of only 12 degrees; the resections of the phalanx allowed an extension of 33 degrees; the plastic operations, 35 degrees, and the excision of exostosis, 28 degrees.

Flexion of the metatarsophalangeal joint was about 10 degrees in all of the various types of operative procedure, except in the removal of an exostosis, which resulted in an average flexion of 18 degrees.

Control of the toes was much better in the excisions for exostosis, which showed 92 per cent good or excellent results. The resection of the metatarsal heads and resection of the phalanx showed 70 per cent and 82 per cent good or excellent results, respectively, while the osteotomy and plastic procedures yielded only 41 per cent and 60 per cent of good or excellent results.

These results bear out the feeling that the less one interferes with the joint surfaces of the first metatarsal and the proximal phalanx, the greater will be the subsequent mobility of the joint. The exception to this is the joint with distinct limitation of motion of the hallux rigidus type (table 4).

*The Foot as a Whole.*—The anterior arch was found to be severely impaired in 101 patients before operation, and in 128 after operation, and slightly impaired in 39 patients before operation, and in 28 after operation. So there was apparently an increase in this deformity in spite of operative procedure and postoperative treatment.

This increased impairment in the anterior arch is due to shortening of the metatarsal head, which disturbs to some extent the normal three point support of the foot, that is, the heel and the heads of the first and fifth metatarsal bones. In making a resection of the head of the metatarsal, a minimal amount of bone should be removed.

The influence of the flattened or inverted anterior arch is shown in table 1. In comparing the cases in which there were severely or moderately impaired anterior arches, noted before operation, with those pre-



From the clinical course and from the fact that lamination of the walls of the hematoma has occasionally been described, it has been assumed by some that repeated fresh hemorrhages may occur within the cyst. As Putnam says, the "question is still an open one although in some instances it would seem that such an event must occur to account for the clinical picture." With the exception of the deformity of the brain which is caused by displacement from the overlying clot, grossly or microscopically little is seen in this organ that is pathologic. Thickening of the vessels and areas of cerebral softening may occur, but probably not more frequently than in normal persons of corresponding age. After removal of the hematoma, the cerebral functions fully recover with amazing rapidity. The skull shows little change. In certain instances there is undoubtedly an increased vascularity of the bone, but whether this is due to the underlying hematoma or is merely a normal variation in individual skulls, is not yet clear.

All observers agree that the symptomatology in these cases is characterized by its variability. Trauma, as a clinical and causative factor, is often so slight and ancient as to be almost forgotten. A bump on the head, a fall not accompanied by unconsciousness, a slap in the face, a blow received in boxing, an injury in football scrimmage or even repeated slight trauma, as in Trotter's case in which a workman frequently bumped his head against a low-lying beam in the workshop, or in the case cited by Kasemeyer, in which children were subjected to abuse by their guardians, have been reported as causative factors. In some instances the trauma is undoubtedly severe, causing concussion and confusion of the brain and even fracture of the skull, as in case 6 of this series. Trotter believes that injury received in the frontal or occipital region is more likely to give rise to a slow hemorrhage than if it were received on the side of the head, as the falx acts as a buffer

senting but slight impairment or none, it is seen that in the first group there is a smaller number of good or excellent results. Good results were obtained in all cases in which the anterior arch was not impaired or only slightly flattened. Unquestionably, a foot with a severely impaired anterior arch is more difficult to deal with than a relatively normal foot (table 1).

Callosities beneath the metatarsal heads were unaffected or increased in 73 per cent of all cases, and they were improved in 27 per cent.

Dorsal Flexion: Before operation, dorsal flexion was found to be limited to 95 degrees and over in 135 cases, and after operation it was

TABLE 1.—*The Effect of Flattening of the Anterior Arch on the End-Result*

End-Result	Moderate or Severe, Percentage	Slight or None, Percentage	Entire Series, Percentage
Excellent.....	35	49	40
Good.....	33	40.6	36.5
Fair.....	18	10.2	16
Poor.....	13.2	..	7.5

TABLE 2.—*Influence of Preoperative Arthritis on End-Result*

End-Result	Slight, Percentage	Moderate, Percentage	Severe, Percentage	Entire Series, Percentage
Excellent.....	43	24	8	40
Good.....	14	48	16	36.5
Fair.....	28	7	42	16
Poor.....	14	21	32	7.5

TABLE 3.—*Influence of Postoperative Arthritis on End-Result*

End-Result	Slight, Percentage	Moderate, Percentage	Severe, Percentage	Entire Series, Percentage
Excellent.....	45	4	..	40
Good.....	55	48	..	36.5
Fair.....	..	11	25	16
Poor.....	..	37	75	7.5

thus limited in 100 cases. The difference corresponds almost exactly to the thirty-four cases in which the achilles tendon was lengthened for symptoms referable to a short calf.

Pronation was noted as moderate or severe before the operative procedure in 138 cases, and in 136 afterward. Operation did not make any essential change in this respect.

*Arthritis.*—Arthritis in the joint of the great toe before operation had a marked effect on the end-result. Fifty-five cases gave evidence of active arthritis in the metatarsophalangeal joint before operation. The presence of arthritis was determined by roentgen-ray examination in six of these cases. Table 2 shows the high percentage of cases with arthritis in which poor or fair end-results were obtained.

may vary in time, lasting from a few days to several months or even years. Usually the symptoms are those of increased pressure which progress in an irregular manner. Headache is perhaps the most common symptom and may be merely a slight dull ache or a severe pain. While there is nothing definitely localizing in the location of the pain, frequently it is most severe on the side of the hemorrhage. Nausea and vomiting may be associated with the headache. Vertigo is likely to be a prominent symptom especially suggestive of frontal lobe or cerebellar localization. In two of the cases in this series, much time was given to considering whether the lesion was frontal or cerebellar. A true cerebellar ataxia was not seen, but the patient swayed in Romberg's position, and at times showed a decided tendency to pitch backward. An atypical nystagmus or roving of the eyes may be present, which is generally of horizontal or mixed character. Double vision may occur, but is usually transient. The temperature hovers around normal or may vary from subnormal to about 100 degrees. Some authors claim that periods of rise in temperature are associated with fresh bleeding into the hematoma. The periods of subnormal temperature raise the suspicion of brain abscess.

The mental condition in some instances may act as a fair index of the pathologic condition. Many cases have been reported from institutions for the insane. The patients are likely to be irritable, untidy, obscene—in short, almost unmanageable. In a recent case in which the pathologic condition was not definitely proved, for months the patient was disoriented as to time and place, carried on conversations regarding irrelevant matters, and at times required restraint. At other times, his mental condition was clear and normal. Symptoms of this nature may run on for indefinite periods, the patient presenting signs of increased intracranial pressure with few, if any, localizing signs. There may be bilateral choked disks which gradually show increasing elevation, with hemorrhages and exudates present. Frequently, the process is more marked on the side of the hemorrhage. General or focal convulsions may occur, which may be associated with, or usher in, the terminal phase of the disease. In three of the six cases reported, the patient had jacksonian attacks shortly before operation, these attacks being the most reliable localizing sign. In all of them, there was twitching of the contralateral arm and face, the leg not participating except when the attack became general. Mild seizures may occur in which the patient is conscious but describes a transient numbness of the hand or face, not associated with any motor manifestations and disappearing in a few minutes. For the most part, repeated examination of the reflexes may not help to localize the lesion, although ultimately the patient may show a definite inequality of both superficial and deep reflexes which indicates the side of the lesion. This was true in four

After operation, at the final examination, arthritis was noted in forty-six cases. The percentage of poor results is very high among the patients who had this complication in moderate or severe degree (table 3).

In view of these observations in regard to the influence of arthritis on the end-results, it is worth while to institute antiarthritic measures in any case of hallux valgus which presents the slightest evidence of an arthritic tendency.

#### COMPARISON OF THE OPERATIVE PROCEDURES

In comparing the various types of operative procedures, it would be unfair to condemn any of those which were used in only a few cases. In my experience, however, the resection of the metatarsal head has been the most satisfactory procedure in the greatest number of cases. It has given good flexion and extension and control of the toe, a marked

TABLE 4.—*Comparative End-Results*

	Hallux Valgus Improvement in Deformity, Degrees	Average No. of Degrees of Extension of Great Toe	Average No. of Degrees of Flexion of Great Toe	Control of Toe, Good or Excellent, Percentage	Good or Excellent Cosmetic Results, Percentage	Good or Excellent Functional Results, Percentage
Resection of metatarsal head.....	21	42	9.5	70	88	82
Excision of exostosis.....	5	28.5	18	92	47	86
Resection of proximal end of first phalanx.....	20	33	10	82	63	50
Plastic repair together with excision of exostosis.....	8	35	13	60	73	65
Osteotomy.....	20	32	8	41	70	28

improvement in the deformity and a large percentage of good or excellent results. The simple excision of exostosis, together with at least one third of the metatarsal head, does not attempt to correct the deformity, per se. It does not interfere in any way with the joint and gives good mobility and control of the toe, and, by removal of a painful deformed overgrowth of the bone, makes the foot infinitely more comfortable. If properly performed, with wide excision of the exostosis and removal of the projecting lip on the first phalanx, it is a satisfactory procedure.

Table 4 shows a comparison of the end-results obtained in each of the various operative procedures.

#### CAUSES OF FAILURE

The most important cause of failure to achieve a good result must be attributed to arthritis in the metatarsophalangeal joint. Many of these arthritic patients should perhaps not be subjected to operative intervention. If operation is indicated and the mobility of the joint is much limited, a resection should be made. The removal of a painful

patients who were operated on. Motor differences in the way of slight weakness or spasticity of an extremity may be associated with these reflex changes. Aphasia, usually of the motor type, may occur as in two of the cases I have reported. It is usually transient and is most aggravated during the period of cortical irritation, which is associated with the jacksonian episode or follows it. The pulse rate is usually slow.

A spinal fluid examination has been of considerable interest in that a varying degree of xanthochromia is frequently present. The fluid may vary from a slight, smoky or blood tinged color to a deep yellow or straw color, finally becoming clear. The character of the fluid depends largely on the length of time that has elapsed from the onset of the hemorrhage until the lumbar puncture was performed. Spinal fluid tests were performed on five of the six patients I observed; the pressure was increased in three, and the manometric readings were 200 mm., 400 mm. and 325 mm., respectively, by water manometer. In the fourth instance the spinal fluid was recorded as normal. In one instance, the first puncture, taken about a week after the injury showed a smoky, slightly cloudy fluid and contained 14 cells per cubic millimeter. About ten days later, the spinal fluid showed a definite xanthochromia with 18 cells per cubic millimeter. In another instance, a lumbar puncture, which was made approximately three months after the injury, showed a light straw colored fluid containing 5 cells per cubic millimeter. In one instance, the spinal fluid taken five months after the injury showed a pale straw tint with 2 cells per cubic millimeter; and in the last instance, the study made of a patient five months after the injury, showed a clear fluid and 1 cell per cubic millimeter. It is probable that the last case would have shown some degree of xanthochromia had a lumbar puncture been performed earlier. In one case a lumbar puncture was not performed on the patient because of the high degree of intracranial pressure present and the fear that if the lesion were cerebral, a formation of the meninges might result.

exostosis is a useful procedure in many of these cases in which there is relatively free motion in the metatarsophalangeal joint.

Severe deformity of the foot as a whole, especially of the anterior arch, must be acknowledged as predisposing to a poor result. None of the operative procedures will rehabilitate completely a deformed foot with inverted anterior arch, metatarsalgia and widespread first interosseous space.

In patients with badly deformed feet, postoperative treatment, such as proper shoes or perhaps foot plates, is essential and is usually facilitated by the removal of the painful bunion.

In addition to these detrimental predisposing factors, some of the causes of failure to help these patients as observed in the last eighty cases of the series are given in the following paragraphs.

*Inadequate Excision of Deformed Bone.*—(a) Failure to remove enough of the metatarsal exostosis was noted in eleven cases, in one of which the patient has subsequently been operated on a second time. (b) Failure to remove the exostosis or projecting lip on the dorsal or medial surface of the proximal phalanx was a cause of complaint in ten cases (fig. 2).

*Sesamoids Beneath the First Metatarsal Head.*—Painful sesamoids which had not been recognized were a cause of complaint in four cases and were subsequently removed in two of them. These are examined regularly now, and if they are tender or show hypertrophic changes they are excised.

*Failure to Select the Proper Operative Procedure or Poor Technic.*—

Three patients who have been subjected each to a different operative procedure, with poor end-results, have been advised to return to the hospital for a resection of the metatarsal head. The selection of this more radical procedure in the first place might have avoided a poor result.

#### CONCLUSIONS

1. In this series the most satisfactory operation for correction of hallux valgus was resection of the metatarsal head, together with removal of exostosis.

2. In selected cases with only moderate hallux valgus and in which the patients complained of a painful exostosis and inflamed bursa as the chief source of annoyance, wide excision of the exostoses alone gave satisfactory results.

3. Other operative procedures have not been found as satisfactory.

4. The presence of chronic arthritis in the joint of the great toe predisposes to an unfavorable outcome in direct proportion to its degree of severity.

as the procedure of choice. The postoperative course in the majority of cases has been more or less stormy. This has been attributed to edema of the brain following removal of the clot. Several patients have been studied in whom the wound was reopened several days later, because it was thought that a secondary hemorrhage had occurred; a tight swollen brain was almost invariably found. There is apparently little danger of bleeding from the under surface of the dura and even less from the pial surface of the brain following the removal of the linings of the hematoma. Undoubtedly there is, for the time being, an excessive accumulation of cerebrospinal fluid. In four of my cases an osteoplastic flap was performed on the patients with the removal of the hematoma and membranes, and in two of these decompression openings were provided. In all instances there was a rather sharp temperature reaction immediately following the operation and a moderate amount of elevation of the flap. After the first two operations, drainage was not employed, and it was necessary to open the scalp enough to allow the escape of the fluid. This continued for a week or ten days, then ceased. In two cases, drainage was provided, the drain being removed on the second or third day following the operation. In both of these instances there was a rather copious drainage for a week, which gradually ceased. In one instance, a simple decompression was made, with evacuation of the contents of the hematoma, but the capsule was not removed. The patient's recovery was prompt and satisfactory. Trotter states that not infrequently these hematomas may be bilateral, and Putnam suggests that exploratory cranial dural puncture over the suspected hemisphere "will give most reliable evidence of the presence or otherwise of a clot." In one case when the patient was thought to have a chronic subdural hemorrhage, I used this method, making four trephine openings in the skull and opening the dura enough to pass a brain spoon beneath. Hemorrhage was not encountered over either hemisphere, and the subsequent recovery of the patient would seem to indicate that a massive clot had not formed.

#### CASE REPORTS

*CASE 1.—Chronic subdural hematoma, right side, occasioned by fall, striking occiput. Immediate symptoms trivial—gradual development of pressure symptoms and headache. Few localizing signs; side of lesion revealed by ventriculography. Death six months after injury—large encapsulated subdural hemorrhage disclosed at autopsy.*

*History.*—A man, aged 53, married, a butter cutter, was admitted to the Los Angeles General Hospital on Aug. 23, 1923, in a stuporous condition. He could be roused enough to whisper, but did not give intelligent answers. Four and a half months previously he had been in an automobile accident in which his right shoulder was dislocated and his scalp lacerated. The injury of the head was not considered severe. After staying in a local hospital for two days, he was sent home. He soon began to complain of headaches. At first they were not

5. An anterior arch that is severely impaired is a serious handicap in achieving a good result in the operative treatment of hallux valgus.

6. Inadequate excision of the metatarsal and phalangeal exostoses leaves bony spicules which cause subsequent pain. Care should be taken to remove all loose fragments of bone or bone sand.

7. The sesamoids beneath the metatarsal head should be examined as a cause of pain, and removed if necessary.

8. The proper selection of the operative procedure to fit the individual case is of great importance.

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severe, but on some occasions kept him awake at night. After six weeks the headaches became constant and more severe. Nausea and vomiting never accompanied the headaches, and there were never any convulsions. About a week prior to his admission to the Los Angeles General Hospital, he refused to take an automobile ride because he had a severe headache. The following day, he became drowsy and remained in a condition of alternate drowsiness and irritability until his admission. The stupor gradually increased during the preceding three or four days, and at times amounted to coma.

*Examination.*—This revealed a large, well built man, breathing heavily and difficult to rouse. In the occipital region was a small scar under which a small dent in the skull could be felt. On looking to either side, the eyeballs showed slight oscillation but not a true nystagmus. The eyegrounds showed a double choked disk of long standing, with complete obliteration of the disk margins, embedding of the veins, filling in of the optic cup with new tissue and an occasional small retinal hemorrhage. It was estimated that the swelling was about 5 diopters. Aside from possibility of a slight weakness of central origin on the left side of the face, nothing abnormal was noted in the cranial nerves. The patient would move all extremities on stimulation without marked discrepancy in their use. At times it was thought that the left arm and left leg were slightly less strong than the right, but they were not spastic. There was a coarse ataxic tremor of both arms and some ataxia of the legs. Apparently sensation was retained everywhere. The abdominal, epigastric and cremasteric reflexes were all sluggish but seemed equal. The biceps reflexes were active and equal; triceps, wrist and finger reflexes were sluggish and equal; the knee and ankle reflexes were hyperactive, but seemed equally so. There was a questionable Babinski sign on the right and left; ankle clonus was not present on either side. The spinal fluid, which was a faint straw color, was under 200 mm. pressure, contained 2 cells and did not show any increase in globulin content. The blood pressure was 137 systolic and 76 diastolic. The blood examination showed: red blood cells, 6,000,000; white blood cells, 5,400; hemoglobin, 80 per cent; polymorphonuclears, 78 per cent; large lymphocytes, 5 per cent; small lymphocytes, 14 per cent, and transitionals, 3 per cent. Roentgenograms of the skull showed an old depression of the outer table of the skull almost in the midoccipital position. Little, if any, depression of the inner table was noted.

# CHRONIC SUBDURAL HEMATOMA .

## REPORT OF SEVEN CASES \*

CARL W. RAND, M.D.

LOS ANGELES

During the summer of 1923, a group of clinicians were puzzling over the condition of a patient who had been admitted to the neurosurgical service of the Los Angeles General Hospital, suspected of having a tumor of the brain. Localization of the lesion by ordinary methods of neurologic examination proved baffling, but was finally accomplished by the inflation of the ventricles with air. The night before exploratory craniotomy was to have been performed, the patient suddenly died, and at the autopsy an unsuspected type of chronic subdural hemorrhage was discovered. At the time this case was unique in my experience, although since then six additional cases have been encountered, which, together with the first, form the basis of this report.

These cases differ symptomatically and pathologically from the meningeal type of epidural or subdural hemorrhage which usually follow injuries of the head, and more closely resemble the picture of pachymeningitis hemorrhagica interna of spontaneous origin. They all have been relatively late sequelae of major, or more commonly, of minor injuries of the head, and the patients have come to operation or autopsy at periods varying from six weeks to eight months after trauma. The pathologic condition has been almost the same, namely, a circumscribed massive subdural hemorrhage in varying stages of formation or recession, in each instance surrounded by a discrete capsule. Putnam and Cushing<sup>1</sup> recently made an exhaustive study of chronic subdural hematoma, in which they point out that such cases are more common than had been thought probable. They discuss the pathologic condition, especially in relation to pachymeningitis hemorrhagica interna of non-traumatic origin, and have given valuable hints as to the operative treatment. I have drawn freely on their discussion in the consideration of the subject.

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\* This rare type of late subdural hemorrhage of traumatic origin has been discussed in the literature under many and varying names. It has perhaps been most frequently referred to as traumatic subdural hemorrhage, encapsulated subdural hemorrhage, chronic subdural hemorrhage, encysted subdural hemorrhage, pachymeningitis hemorrhagica interna, pachymeningitis hemorrhagica interna traumatica, hematoma durae matris, etc. The term chronic subdural hematoma is perhaps becoming more frequently used and has been chosen because it seems to fit the pathologic conditions more consistently than any other.

1. Putnam, T. J., and Cushing, H.: Chronic Subdural Hematoma, Arch. Surg. 11:329 (Sept.) 1925.

Had a right subtemporal decompression been performed to relieve the pressure, the hemorrhage would have been disclosed, and it is not unlikely that the outcome would have been different.

*CASE 2.—Chronic subdural hematoma, left side, with gradually increasing signs of increased pressure for six weeks, following injury sustained in boxing. Jacksonian episode and aphasia developed late. Removal of hematoma at operation. Recovery.*

*History.*—F. R., a man, aged 42, married, physician, was first seen on Nov. 8, 1923, in consultation with Dr. H. Douglas Eaton of Los Angeles. The patient used alcohol in moderation. His general health had always been good. While his acute symptoms dated from October 24, he had been subject to headaches for several weeks prior to that date. About a month earlier, the patient decided that he was putting on too much weight and that he needed more exercise. He started strenuous daily gymnastic work, principally boxing. He noticed that his headaches became severe during exercise, so that at times he had to stop and rest. He complained of stiffness of the neck and pain at the back of his head, and he would frequently press his head forward against his hands for relief. During the last week in September, he received a severe blow on the nose which did not knock him down. During the boxing bouts he never received a knockout blow. The week following this blow on the nose, he was logy and more drowsy than usual; the discomfort in the back of his head and neck was more marked. On October 26, he attended to his practice as usual and boxed an hour and a half. During the match he received a blow over the right eye sufficient to cause ecchymosis and to bring him to his right knee; however, he was not unconscious, nor did his head strike the floor. After the exercise he finished his office work, in spite of a severe headache. He was more drowsy than usual at dinner time. His headache continued to grow worse. About 8 p. m., he took 10 grains (0.6 Gm.) of acetylsalicylic acid and a hot bath before retiring. Later he took  $\frac{1}{2}$  grain (0.03 Gm.) of codeine and mild mercurous chloride by mouth and immediately vomited large quantities of bile stained fluid. He slept well all night. The next morning, October 27, he felt some better, and that afternoon dressed and went downstairs, where he spent most of the time lying down. His headache was still severe and that night he was restless, twitched in his sleep, and between 3 and 4 o'clock in the morning had a generalized spasm. He was unconscious, his color was ashy, and all extremities were in a generalized convulsion. His head was drawn to the left, his teeth were clenched, and he frothed at the mouth. The coma lasted from thirty minutes to an hour. On waking, a difficulty of speech was noticed; in fact, his speech was thick and mumbling until late in the morning. About 3:30 that afternoon, while lying on the couch talking to his wife, the patient felt that he could not speak. He got up, walked over to a table and started to write a message. The writing was steady, but there was repetition of the words and the whole product was without meaning. He then had a generalized convulsion, more severe and longer than the previous one, but with the same general characteristics. Dr. Eaton saw him at 8 o'clock that evening, and the results of his examination are given in the following paragraph.

*Examination.*—The patient was lying quietly in bed. He was conscious and apparently ill, but not extremely so. The color of the face was dusky, somewhat cyanotic. The nutrition was good. There was no evidence of injury to the scalp. The face was somewhat asymmetrical, but this was a normal characteristic; the left side was flatter and the left corner of the mouth was lower. There were pouches under both eyes, which seemed to indicate fairly rapid and recent loss of

Chronic subdural hematoma has long been recognized under various names, although the majority of the earlier cases were apparently considered to be of the nontraumatic variety. It is probable that even in the earlier reports, an overlooked injury to the head may have preceded the formation of the clot, since in the more recent reports of typical cases, the injury was not infrequently slight, in some instances so trivial as to be given little consideration. Among the earliest writers, Wepfer<sup>2</sup> referred to the lesion as a "blood-cyst," and later, Houssard<sup>3</sup> accounted for the surrounding capsule as being made up of fibrin, while others have supposed it to be composed of the inner and outer layers of the dura, which were split and thus surrounded the clot. Gradually, the idea of inflammation developed, which probably accounts for the term *pachymeningitis hemorrhagica interna* being used in describing these cases. Virchow<sup>4</sup> gave the first clear description of the true position of the hemorrhage in its relation to the surrounding envelopes of the brain. He demonstrated that it does not lie within the layers of the dura, or under the arachnoid membrane, but in the subdural space. He assumed that in some elderly people there might be a chronic thickening or inflammation of the dura, with resulting fibrin formation. Under certain conditions of strain the capillaries that had grown into the fibrin gave way and small hemorrhages formed. He used the term *pachymeningitis chronica interna* for the cases which did not show gross hemorrhage, and *pachymeningitis hemorrhagica*, for the cases in which massive hemorrhage occurred. He called the blood cysts, hematomas of the dura, and pointed out that under certain conditions they might become massive, in which event they were usually fatal.

Spontaneous *pachymeningitis hemorrhagica interna* may occur in a person who uses alcohol extensively. Kremiansky<sup>5</sup> was able to obtain a close reproduction of the lesion by feeding brandy to dogs. Sperling<sup>6</sup> injected whole blood under the dura and reported a resulting membrane about the clot which, in some respects, resembled the spontaneous lesion. Injections of defibrinated blood probably would not give this result. Many observers had considered the lesion inflammatory in the sense that fibrin accompanied its formation, but bacteria were never recovered

<sup>2</sup> Wepfer, J. J.: *Observationes Anatomicae ex Cadaveribus eorum, quos sustulit apoplexia*, Amsterdam, p. 5, 1681.

<sup>3</sup> Houssard, M.: *Observation d'un kyste considerable developpe dans la cavite de l'arachnoide chez un sujet qui a succombe avec les symptomes d'une apoplexie cerebrale*, *Revue med. et ch.*, Paris **55**:67, 1817.

<sup>4</sup> Virchow, R.: *Hematoma Durae Matris*, *Verhandl. d. phys-med. Gesellsch. zu Wien*, **7**:134, 1857.

<sup>5</sup> Kremiansky, J.: *Ueber die Pachymeningitis interna hemorrhagica bei Menschen und Hunden*, *Arch. f. path. Anat.*, **42**:129 and 321, 1898.

<sup>6</sup> Sperling, M.: *Ueber Pachymeningitis Hemorrhagica Interna*, *Quartalsber. Anat. u. Physiol.*, **18**:72, 1872.



from the contents of the sac. Barrett,<sup>7</sup> Rosenberg,<sup>8</sup> Budinger<sup>9</sup> and others failed to find bacteria, either in smears or cultures taken from their specimens. It was Kasemeyer,<sup>10</sup> perhaps, who gave the first proof of the relation of trauma in these cases and emphasized the fact of the late occurrence of the symptoms.

There is a great similarity in the pathologic condition seen in chronic spontaneous hemorrhages and those of traumatic origin. In each instance, the clot is surrounded by a distinct lining or neomembrane which is thicker on the dural side and thinner on the arachnoid side. Lamination of the walls has been described by Wiglesworth<sup>11</sup> and other observers, but it is not frequently seen. The subdural neomembrane usually measures from 1 to 4 mm. in thickness; it is opaque, well formed and composed of fibrous tissue. It is moderately adherent to the dura by fine senescent bands, leaving a denuded area of petechial hemorrhage generally distributed under this membrane, from which it can easily be separated. The membrane contains capillaries in varying numbers and varying stages of formation, and in many ways resembles ordinary granulation or fibrous tissue, depending largely on its age. Putnam has called attention to the fact that "the characteristic feature of the membrane is the presence of large spaces of irregular form but in general elongated, most of which lie in a definite uniform line parallel to the surface of the dura, separated from it by the thickness of a few fibroblasts." These spaces are lined by definite mesothelial cells. Putnam considers the spaces as characteristic of the reaction to the traumatic type of subdural hemorrhage; they are seldom, if ever, seen in the spontaneous form of pachymeningitis hemorrhagica interna. He states:

In general it appears that the longer the interval between the trauma and the removal of the specimen, the larger and more irregular are the spaces. . . . The fact that the spaces described are removed intact when the membrane is stripped from the dura instead of forming a line of cleavage in themselves, is evidence that their walls have a definite strength and structure and are not artefacts.

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7. Barrett, J. O. W.: On Pachymeningitis Hemorrhagica Interna, *Brain* 25:181, 1902.

8. Rosenberg, O.: Die Pachymeningitis hemorrhagica interna im Kindesalter, *Ergebn. d. inn. Med. u. Kinderh.* 20:549, 1921.

9. Budinger, K.: Die Ursachen der Spatsymptome nach duralen Blutungen, *Med. Klin.* 17:584 (May 15) 1921.

10. Kasemeyer, E.: Ueber post-traumatische Pachymeningitis unter dem Bild der post traumatischen Neurosen, *Friedrich's Bl. f. gerichtl. Med.* 62:293, 339 and 401, 1911.

11. Wiglesworth, J.: Remarks on the Pathology of the So-called Pachymeningitis Interna Hemorrhagica, *Brain* 15:431, 1892.



Von Saar and Herschmann<sup>12</sup> have observed similar spaces. Degenerative progressive changes may occur in the subdural membrane; even calcification has been described by Lewis<sup>13</sup> and Elsner,<sup>14</sup> and fatty degeneration of the vessels is mentioned by Charcot and Vulpian.<sup>15</sup> Huegenin<sup>16</sup> found fatty degeneration and thrombosis of the cerebral veins in the pia, and at their entrance to the longitudinal sinns, and he described cases in which points of rupture of these vessels were noted both in the pia and near the sinns. This condition has occurred in three patients in the cases reported, and it would seem that bleeding from the pial vessels is one of the sources of the hematoma.

The inner or arachnoid portion of the membrane is much thinner than the dural side, and is translucent or semitransparent. It is essentially avascular, and consists of a thin sheet made up of several layers of mesothelial cells. For the most part, it lies almost free over the underlying arachnoid, although it may be loosely attached to this membrane here and there by fine bloodless synchias, and can be separated easily from its arachnoid surface by blunt dissection. After its removal, the pia-arachnoid usually presents a yellowish tinge. In one of Putnam's cases, it was studied microscopically and found to be normal. The yellow color of the arachnoid and the pia is assumed to be due to the transformation of hemoglobin into biliverdin and bilirubin by the reactive powers of the mesothelial cells of the arachnoid, of which the inner wall of the hematoma is composed. Some observers have described a thickening of the arachnoid with adhesions to the neomembrane. This is particularly true in experimental animals. Ramaer<sup>17</sup> and Hassin<sup>18</sup> placed considerable emphasis on this and regarded the arachnoid as the primary seat of the disease, with the underlying pial vessels as the source of hemorrhage. Trotter<sup>19</sup> likewise feels that there can be little doubt that the bleeding is of venous origin, and "that it is nearly certain that the cerebral veins passing from the brain to the tributaries of the superior longitudinal sinns are nearly always the source of the blood."

12. Von Saar and Herschmann: Zur Symptomatologie und Therapie der Pachymeningitis haemorrhagica interna, Deutsche Ztschr. f. Chir. **145**:398, 1918.

13. Lewis, B.: Textbook of Mental Disease, London, p. 434, 1889.

14. Elsner, K.: Ueber Pachymeningitis Ossificans, Quangel's Dissertation, Mergel, 1876.

15. Charcot and Vulpian: Sur les neomembranes de la dure-mere, Gaz. heb. Semid. Paris **7**:728, 789 and 821, 1890.

16. Huegenin, O.: Zwei Falle von Pachymeningitis interna haemorrhagica nach Trauma, Ztschr. f. Klin. Med. **38**:451, 1899.

17. Ramaer: Bemerkung zur Abhandlung uher das Hamatom der Dura Mater von Dr. G. Weber, Arch. f. path. Anat. **21**:223, 1892.

18. Hassin, H. B.: Histogenesis and Pathology of Subdural Hemorrhages, Med. Rec. **94**:1000-1003, 1913.

19. Trotter, W.: On the Subdural Hemorrhage of Traumatic Origin, and Its Relation to Pachymeningitis Haemorrhagica Interna, Brit. J. Surg. **2**:271, 1914.





(However, he states "that the enclosing membrane seemed to be derived from the organization of the outer layer of the clot . . . and it is not impossible that the arachnoid contributes to the inner layer of the cyst".) In two patients of my series this seemed to be true. The neomembrane in one was found to be locally thickened and tightly adherent to the arachnoid, so that in dissecting it away, a small patch of the membrane had to be left in situ (fig. 1). The underlying pial vein was found to be thrombosed on one side and engorged on the other, giving the impression that this was at least a possible source of hemorrhage. In one patient, these adhesions and thrombosis were found in the mid-prerolandic area, and in the second, at the large veins lying at the junction of the rolandic and sylvian fissures.

The location of the hemorrhage is most common in the frontal and parietal regions, and it may frequently be bilateral. Trotter has emphasized this particularly, estimating that the hematomas may be bilateral in from one third to one half of the cases, and has pointed out the surgical importance of such a possibility. Multiple blood cysts have been described; they may occur in the basal meninges or even about the spinal cord, but such instances are probably exceedingly rare. Multiple hematomas have never been reported over the same hemisphere.

The hematoma may vary in size from a petechial formation to a massive clot which may displace a large part of one cerebral hemisphere. The small hemorrhages are undoubtedly far more common than the large, and in all likelihood undergo recessive changes and absorption giving rise to few, if any, clinical symptoms, and pass unsuspected. The large hematomas probably increase slowly in size, which allows the brain to accommodate itself to the gradually increasing pressure conditions, and accounts for the fact that the symptoms are delayed in appearance and that definitely localizing phenomena are rare until the end is near. Cases have been reported in which the hematoma was discovered at operation or autopsy from a few days or weeks to as long as five years following the injury. The contents of the cyst vary largely according to its age. Probably the earliest observation is a black gelatinous blood clot resembling that found in spontaneous hemorrhage from the middle meningeal. Gradually the clot becomes encapsulated; its contents soften and liquefy, and may become coffee colored fluid in which float fragments of black disorganizing clots of varying size; later, the fluid becomes greenish or yellow, closely resembling the contents of a gliomatous cyst. On one occasion, the greenish contents of a subdural hematoma of ten weeks' standing were tested for bile pigments, but none was found. If time enough elapses, the fluid may become colorless. Virchow recognized this, and believing that the contents eventually contained clear serum, gave the name "hygroma of the dura" to the condition.



The patient received no prophylactic treatment of any kind; she was well when last traced, more than three years later.

**CASE 29.**—*Periosteal sarcoma of humerus, with pulmonary metastases; clinical and roentgen-ray diagnosis; recovery under toxin treatment alone; well eight years.*

B., a man, aged 24, while riding on an engine, lost his balance and fell, striking the running board and receiving a severe strain of his shoulder. Shortly after-

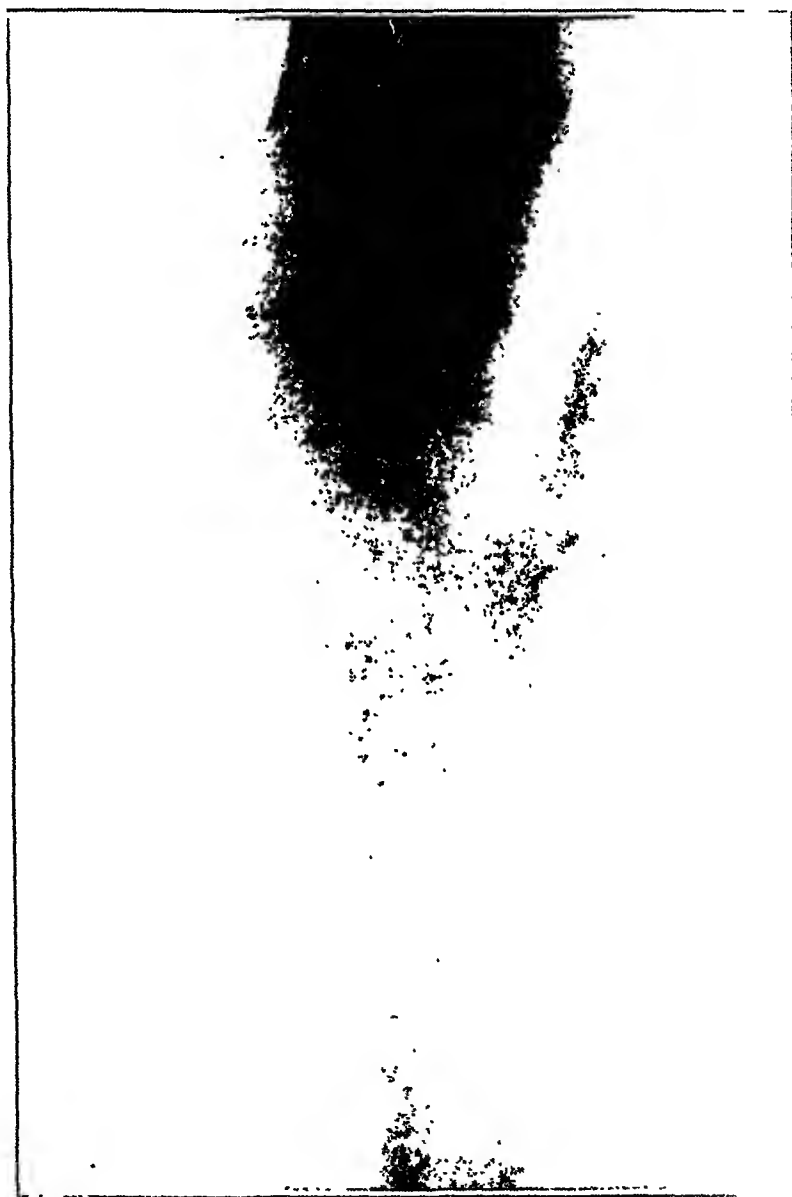


Fig. 56 (case 122 in table 7).—Central sarcoma of femur; clinical and roentgen-ray diagnosis: benign giant cell tumor; no improvement under prolonged radiation; proved a malignant central sarcoma. The patient died one year later.

ward he felt pain, and later a swelling developed in the upper end of the humerus; this grew rapidly, involving the whole upper end; the veins were markedly dilated. A spontaneous fracture occurred shortly afterward. Roentgen-ray examination showed a metastatic growth of the lung.

An exploratory operation was performed by Dr. L. D. Mackid of Calgary, Canada, in February, 1918, at which time a large amount of gelatinous sarcoma-like material was evacuated; the condition was regarded as hopeless from a surgical point of view. In March, 1918, Dr. Mackid began the use of the mixed toxins, pushing the dose to the point of producing a severe reaction. At the end of two months the disease was apparently under complete control; there was no further increase in the size of the tumor and it gradually grew smaller. The toxin treatment was kept up until July, when he was given a rest of three months, after which the injections were resumed by our advice. The spontaneous fracture reunited, the patient gradually regained complete use of his arm, and his general health returned to normal. He was still in excellent condition, and working on a farm, seven years later. Roentgenograms were taken before and after treatment. The patient was well in July, 1926, eight years later.

CASE 30.—*Osteochondrosarcoma of humerus.* E. J. D., a man, aged 27, with a negative family history, had always been in good health until September, 1917, when, preparatory to entering the army, he was given a series of vaccinations in the muscles of the upper part of the right arm. A few weeks later he complained of soreness at the site of the inoculations, also of loss of function of the arm; a swelling appeared and slowly increased in size. In January, 1919, he was operated on by Dr. James M. Hitzrot at the New York Hospital; a portion of the humerus was resected and grafts from the tibia were implanted.

The microscopic report of Dr. W. G. Elser, pathologist to the New York Hospital, was: "Osteochondrosarcoma; diffuse, infiltrating growth involving the entire bone, extending into the surrounding muscle and fascia; extensive infiltration of muscle tissue. Diagnosis: osteogenic sarcoma." This diagnosis was later confirmed by Ewing. February 28, the patient was referred to us for radium treatment. Physical examination on admission to the Memorial Hospital at this time showed that the wound had healed and there was no evidence of the tumor remaining.

From Feb. 28, 1919, to May 16, 1921, he received 82,417 millicurie hours of radium in the form of a pack at 6 cm. distance. Frequent roentgen-ray examinations were made by Dr. Douglas Quick, who reported as follows: April 12, destructive process advancing in the upper end of resected humerus; May 9, 1919, malignant process in humerus steadily advancing; June 3, 1919, some attempt at callus formation about point of junction with the bone graft; it is very doubtful if there is any advance in the malignant process; June 28, 1919, considerable callous formation but no suggestion of new growth.

A curettage was done by one of us, July 21, 1919, and the specimen was submitted to Ewing for microscopic examination, who reported, "No definite tumor tissue but many dark staining round cells."

The patient was discharged from the Memorial Hospital on Nov. 29, 1919, at which time there was no evidence of a return of the tumor. A recent note from him states that he is still well, more than six years after treatment. This case was reported in the Bone Sarcoma Registry.

CASE 31.—*Periosteal sarcoma of femur; hip joint amputation followed by toxin treatment; patient well three years later.*

H. P., a man, aged 27, with a negative family history, in October, 1912, received an injury to the upper part of the left femur; two or three weeks later he began to have pain in this region, but noticed no enlargement until January, 1912, when he observed a fusiform swelling in the upper part of the femur. This rapidly increased in size, and was accompanied by marked deterioration in general health. The patient was referred to us by Dr. William L. Bradley of New York City,

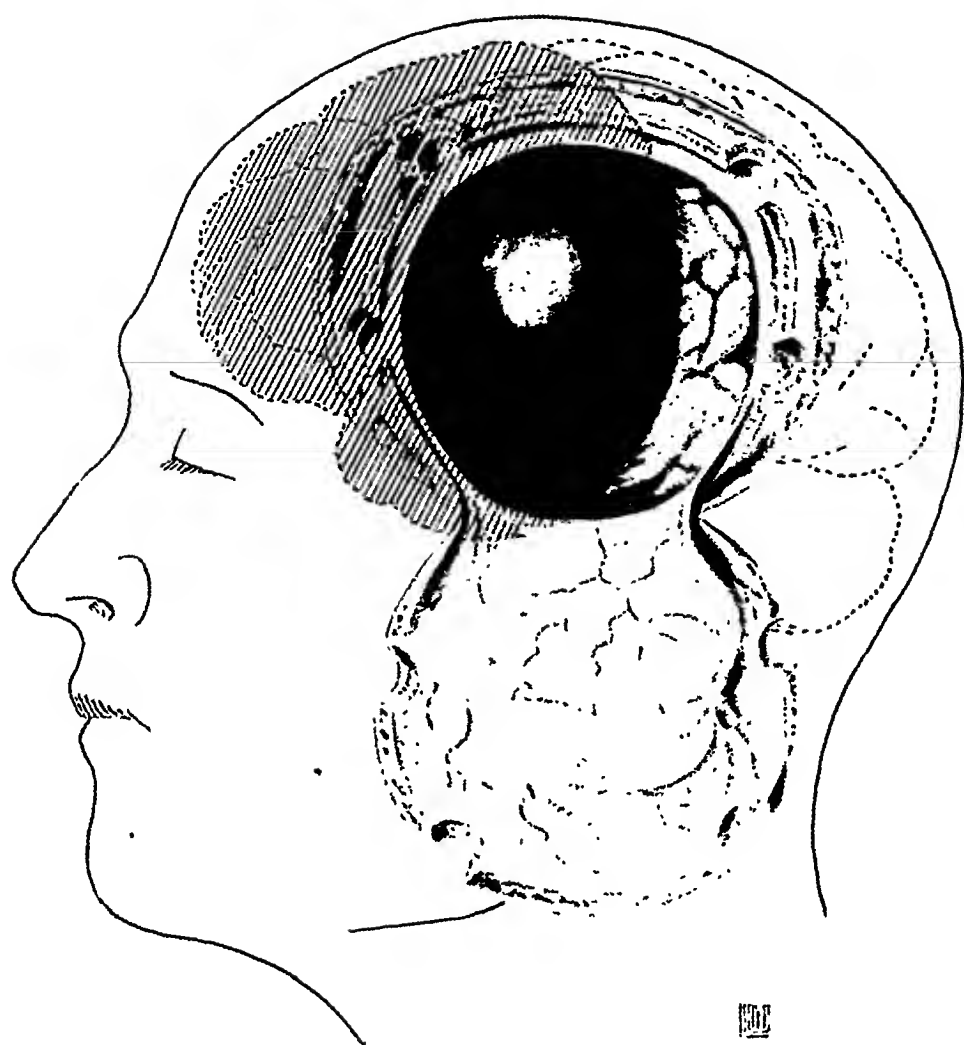


Fig. 5

Fig. 5.—Reproduced from sketches made at operation case 5. Schematic appearance of the hematoma after reflection of the dura. The outer or subdural membrane is shown bulging above the cut edges of the dura. The marked compression of the underlying brain is seen. This usually amounts to from 3 to 6 cm. at the thickest portion of the hematoma. Note how abruptly and concretely the hematoma ends, being attached at its edge to the underlying cortex merely by a thin film of adhesions. The size and location of the entire hematoma is indicated by the shaded area.

*History.*—W. L., a man, aged 62, married, who was first admitted to the Los Angeles General Hospital on Jan. 16, 1926, about 9 o'clock that morning while alighting from a street car had been struck by an automobile and had become unconscious. He was taken to the City Receiving Hospital, and from there transferred to the Los Angeles General Hospital, where he arrived in a stuporous condition. He remembered nothing of what had happened until after his admission to the General Hospital. Later in the day, he complained of intense headache, was nauseated and vomited. He was drowsy at times. There was a hematoma over the right temporal region, with a laceration of the scalp 2 cm. in length.

On January 17, the second day in the hospital, he was conscious, and his mental condition was clear. The lids of both eyes were swollen and discolored. The pupils were equal, regular and reacted sluggishly to light. An examination of the eyegrounds showed the nasal margins of the disks to be hazy and the temporal margins, clear. The vessels did not show any unusual changes. Hemorrhages or exudates were not present, nor any measurable elevation of the retinal structures. Cranial nerve disturbances were not made out, nor were there any motor or sensory disturbances of the extremities. The deep reflexes of the upper extremities were present, unusually active and equal. The knee and achilles tendon reflexes were sluggish, but about equal. Abdominal reflexes of the Babinski group and ankle clonus were not obtained on either side. The patient's temperature varied from 97.8 to 98 F.; the pulse rate, from 64 to 92; respirations remained constant at about 20. Roentgenograms of the skull showed a linear fracture of the right frontal region running down into the right orbit. The case was considered one of linear fracture of the skull and concussion of the brain, the patient going through the usual period of headache. He was allowed up on February 3, eighteen days after the injury. On February 7, he was discharged from the hospital, having been up and about the ward for four or five days. At that time he was not complaining of headache, and he walked out in good condition.

*Examination.*—On March 29, the patient was readmitted to the hospital with a diagnosis of "post-traumatic hysteria." He was confused mentally, did not answer questions, and did not cooperate well on examination. On April 1, it was noticed that the right pupil was considerably larger than the left. Both pupils reacted to light and to accommodation. Nystagmus was not noted. The left grip was considerably weaker than the right, while the strength of the legs seemed equal. The abdominal and epigastric reflexes were normal and equal; the cremasteric reflexes were sluggish and equal, and the deep reflexes of the upper and lower extremities were much exaggerated and about equal; it was questionable whether they were greater on the right side than on the left. Abnormal reflexes of the Babinski group and ankle clonus were not present on either side. The general physical examination, as far as the heart, lungs and abdomen were concerned, was normal. On April 3, his stupor deepened, and during the afternoon he became unconscious. By 8 o'clock in the evening, his coma was so deep that he could not be roused by any ordinary means of stimulation. His pulse rate had dropped to 48. The right pupil was still somewhat larger than the left. An examination of the eyegrounds revealed considerable haziness of the margins of the disk on the right side, with obliteration of the optic cup and moderate engorgement of the veins. The retina appeared normal. Hemorrhages and exudates were not present, nor any measurable elevation, or embedding of the vessels. The fundus on the left side showed a similar picture, except that there was less haziness of the temporal disk margin, and the optic cup could be distinctly seen. The vessels





appeared within limits of normal. The patient's breathing was deep and slow, and on expiration the left side of the face puffed out, possibly indicating weakness of that side. There was marked spasticity of all extremities. The superficial reflexes, abdominal, epigastric and cremasteric were absent. All the deep reflexes of both upper and lower extremities showed great hyperactivity, but were about equal. The Babinski, Oppenheim, Chaddock and Gordon signs were strongly positive on both sides. There was marked ankle clonus on both sides. The spinal fluid was clear, colorless, under increased pressure and contained 7 cells per cubic millimeter, and gave a negative globulin reaction. The blood Wassermann reaction was negative. The urine showed a specific gravity of 1.03, was negative for sugar and acetone and casts. The blood chemistry showed non-protein nitrogen, 40; uric acid, 2.5. It was considered that the patient had a late subdural hemorrhage on the right side, and encapsulation was suspected.

*Operation and Course.*—On April 3, a right subtemporal decompression was performed, with evacuation of the hematoma. On uncovering the dura this membrane was found to be under increased tension and was of a mottled, bluish color. Although pulsation was not visible, when one pressed his finger against the dura, a pulsation transmitted from the brain could be felt. On opening the

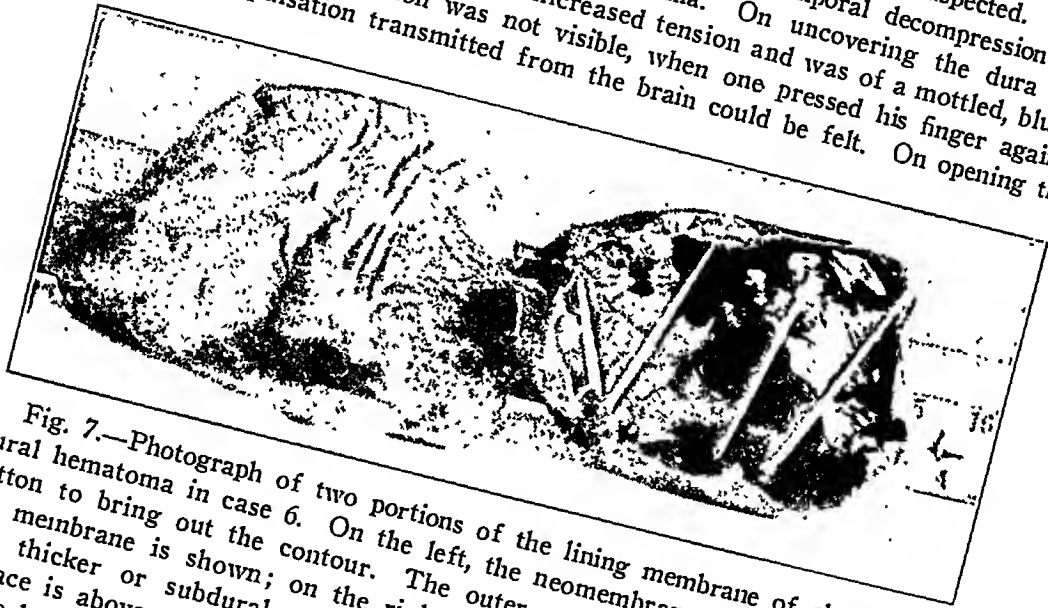


Fig. 7.—Photograph of two portions of the lining membrane of chronic subdural hematoma in case 6. On the left, the neomembrane has been filled with cotton to bring out the contour. The outer surface of the subdural part of the membrane is shown; on the right, one looks into the depths of the sac. The thicker or subdural portion is below while the thinner or arachnoid surface is above. Fragments of the clot can be seen adhering in places. The entire hematoma, which overlay the left frontal lobe, measured 8 by 8 cm. in diameter, and was 8 mm. in thickness.

dura, a typical neomembrane of an encapsulated hemorrhage was found. This adhered loosely to the under surface of the dura by spider-web-like adhesions. The dura was turned back by stellate incisions, and the neomembrane bulged about 0.5 cm. above the opening. A ventricle was introduced through the capsule and about 2 ounces of cloudy, dark-greenish fluid escaped. The outer membrane was opened, and the extent of the hematoma explored with the finger. There were many large flocculi of organized black blood clot floating in the remaining fluid, which were removed manually. After washing out the cavity with physiologic sodium chloride, the finger was introduced and passed about the inside of the sac. This occupied an area overlying the entire frontal, temporal and parietal lobes and thinning out as one went back into the occipital region. It was about 5 cm. in thickness over the frontal and temporal lobes. The inner

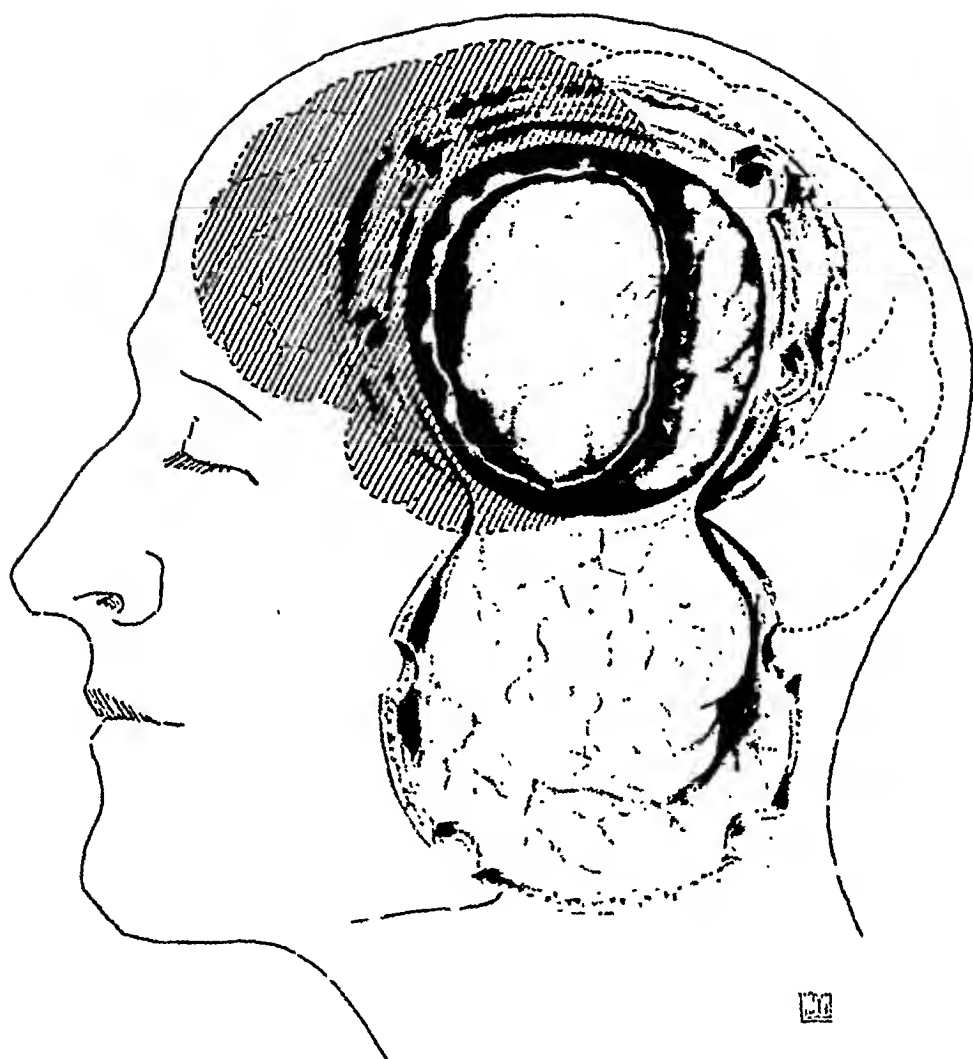


Fig. 6.—Made from sketches taken at operation in case 5. Schematic appearance of the hematoma after the outer membrane had been opened and the contents of the sac evacuated. The inner neomembrane can be seen to be of a light greenish tinge and is translucent. The underlying convolutions of the brain can be seen shining through. This membrane is freely movable over the underlying brain. The greenish tinge is largely due to the transmitted color of the brain which has a decided yellowish tinge underlying the hematoma. The size and location of the entire hematoma is indicated by the shaded area.

neomembrane was examined. It was translucent, the underlying convolutions of the brain being visible beneath it, and as one passed the finger between it and the cortex the membrane separated easily. The gloved finger could be seen almost as plainly through this membrane as if it were not covered. The convolutions of the brain were flattened and the pial vessels congested, but not streaked with new tissue. The arachnoid did not appear to be bluish or thickened. The cortex was of a slight yellowish color. The inner lining membrane of the hematoma was separated from the surface of the brain as far as the finger could reach in all directions, but it was not removed. Sections of the outer membrane and dura were taken for microscopic study. The entire procedure was almost bloodless, as the outer neomembrane was not separated from the under surface of the dura. A folded gutta-percha drain was placed over the cortex and brought out at the lower pole of the incision before a closure was made. The operative time was forty-five minutes.

The patient was conscious on the following morning, but his mental condition was not clear. He used all extremities well. The Babinski sign and ankle clonus which were present just before operation, had almost disappeared. The spasticity of the extremities had disappeared. There was considerable drainage of yellowish cerebrospinal fluid through the dressings. The drain was removed on the second day, and the patient's mental condition rapidly became clear.

*Comment.*—This patient came under observation almost immediately after his accident and remained in the ward for a little more than three weeks, when he was discharged, apparently recovered. Symptoms of acute intracranial pressure were never present, nor were there any localizing signs. His case apparently belonged in the same class as many other cases of injury of the head diagnosed as linear fracture and concussion of the brain; it ran the usual course seen in such cases of moderate severity. A lumbar puncture was not performed on his first admission, as his symptoms did not seem severe enough to indicate it. Following his discharge, a period of approximately seven weeks elapsed before he returned. He was unable to tell what had occurred during this interim, except to say that he had stayed at his boarding house most of the time, and that he had had periods of severe headache. He said that he had stayed in bed a few days prior to his readmission to the hospital; of this time he had little, if any, recollection. After removal of the contents of the hematoma, his mental condition cleared rapidly, and he remembered the period spent in the ward and his attending physicians during his first stay. Looking back on his case, it seems improbable that the hematoma could have been present during the period of his first admission.

The operative procedure in this case was different from that in the others, a simple decompression instead of an osteoplastic flap being performed. This was chosen because of the patient's age, and because his general condition was critical. Simple emptying of the hematoma seems to have given as prompt relief as the more extensive exploration with removal of the membranes. I have the impression that there was less cerebral edema following the decompression than in the other cases.



The fate of the lining membranes of the encapsulated hematoma furnishes interesting speculation. It would hardly seem that there would be as many adhesions to the underlying arachnoid as would result from allowing the brain to press against the raw inner surface of a dura from which the other membranes had been denuded. I doubt if drainage is necessary in cases in which simple decompression and evacuation of the contents of the hematoma are performed. It seems reasonable that there would be less oozing than when a more extensive operation is performed.

*CASE 7.—Chronic subdural hematoma, left side. Patient, a nonagenarian, was struck on the head by an assailant. Unconscious only a few minutes. A period of three months followed during which his mental condition varied greatly. Mental changes were considered as incidental to his age. Autopsy revealed extensive subdural hematoma overlying left frontal lobe.*

*History.*—P. M., a Mexican, aged 90, when admitted to the Los Angeles General Hospital on May 28, 1926, stated that earlier in the day while walking along the street some one came up behind him and struck him on the head. He was stunned by the blow and fell to the sidewalk, breaking the right olecranon. He recovered consciousness in a few minutes, but was still somewhat confused on his arrival at the hospital.

*Examination.*—Examination revealed superficial abrasions of the scalp in the left parietal and occipital regions. The right olecranon was fractured. A small ventral hernia presented in the epigastrium, and was supposed to be a factor in producing attacks of hiccup which were persistent and distressing for days at a time during his illness. He did not complain of headache at any time, nor did he vomit. There were not any unusual irregularities or depressions felt in the calvarium. Roentgenograms of the skull failed to reveal a fracture. Results of the neurologic examination were essentially negative. The pupils were equal and reacted sluggishly to light and distance. Cranial nerve disturbances were not observed. He was never palsied in any extremity. All of the deep reflexes of the upper and lower extremities were present, being about normal and equal. Abnormal reflexes of the Babinski group were not obtained; nor was there ankle clonus on the right or the left side. The blood Wassermann reaction was negative. Spinal fluid studies were not carried out. The urine did not show any albumin, sugar or casts on the patient's admission. During the last two months, the patient was incontinent.

*Course of Illness.*—He was a weak old man, always mentally slow, at times rational, at other times irrational and stuporous. He was greatly annoyed by the periods of hiccup. At times he knew and conversed with his daughter and other members of his family who visited him. He had periods of restlessness and delirium when restraint was necessary, and other periods when he was decidedly drowsy. As time went on he gradually became weaker, and the drowsy spells became more prolonged. During the last month of his life, his friends remarked that "he didn't seem much like himself." Several times he went into a deep stupor, from which he would rouse after a day or two. His nurse said that "he lasted longer than anyone thought he would, and his pulse was good right along." He went into a coma on August 21, and died on August 25, practically three months after his injury. The diagnosis at the time of death was concussion of the brain, fracture of the right olecranon and senility.

weight. There was ecchymosis in the loose tissues about the right eye, but not in the conjunctiva or the sclera. The ears were normal externally. There was no disturbance in the hearing and the ear drums were normal. The eyes did not show any nystagmus, ptosis or paralysis: the pupils were equal and midwide, the reflexes active and normal. The visual fields were roughly normal. Examination of the fundi was unsatisfactory, due to natural smallness and persistent contraction of the pupils under the ophthalmoscopic light. Glimpses of the disk and vessels showed them to be normal, but adequate examination was impossible without dilatation of the pupils. The nose was normal externally: smell and taste were normal. The mouth showed many slight abrasions of the mucous membrane; the tongue was tremendously coated and the breath foul. The teeth and gums were in good condition, and the pharynx showed a slight congestion but absence of exudate. The tonsils were small. The chest was symmetrical; the heart apex, fifth interspace, was normal in size, shape, position and action. The blood pressure was 132 systolic and 80 diastolic; the pulse rate was 66. The arteries did not indicate disproportionate arteriosclerosis for age. The radials were just palpable, the temporals observable and somewhat tortuous. The lungs were normal; the abdomen showed gas in the upper portion, without masses, tenderness or rigidity. The stomach and colon were found to be apparently normal, by percussion. The liver, spleen and kidneys were not palpated. The genitalia were normal. The skin was normal, and the general muscular condition was good. The upper extremities did not show incoordination, tremor or ataxia. The elbow and wrist reflexes were present; they were equal and not exaggerated. The epigastric, abdominal and cremasteric reflexes were active and equal. There was no paralysis of either arm, and the power was good. The right arm showed the normal increase in power over the left. The ankle and patellar reflexes were present and were equal and diminished. Ankle clonus or abnormal plantar reflex to any test was not observed, although there was a question of a pseudo-reaction on stroking the right foot. Sensory disturbance was not present. Sensations of pain, touch and temperature were normal, and accurately and quickly localized. Sensation in the sclera, the conjunctiva and the pharynx was normal. There was no astereognosis or adiadokokinesis; joint and muscle sense was apparently normal, and simple or complex movements were accurately carried out. The Romberg test was suspicious and probably positive. There was slight stiffness of the neck on deep flexion and a slight but definite Kernig sign on both sides. There was distinct difficulty in speech, apparently of the motor aphasia type. Ataxia and anarthria were absent, and evidence of bulbar symptoms was not found.

On October 29, a lumbar puncture showed the spinal fluid to be under greatly increased tension, well over 400 mm. pressure. It was blood streaked and remained so even in the third tube. On standing, however, it became clear. The cell count showed 14 white cells per cubic millimeter and numerous red blood cells. Wassermann tests of the spinal fluid and blood were negative. A red blood count was normal, and the white count showed 6,900 cells with 61 per cent polymorphonuclears. From October 29 to November 7, the patient's condition remained much the same. He varied between periods of restlessness and drowsiness, and realized that he remembered practically nothing of the early part of his illness. His headache was severe at times; at other times mild. His temperature varied from 97 to 100 F., but his pulse rate remained consistently low, from 44 to 58. There was a tendency for the headache to become left-sided, and percussion over the left side of the calvarium caused distinct discomfort. On November 7, he had his third convulsion, a clonic spasm of the right side of the face, arm and leg, accompanied by marked motor aphasia. The left pupil was larger than the right,

*Autopsy.*—The coroner's report follows: "The brain was small and atrophic. Over the left frontal lobe there was an extensive encapsulated subdural hemorrhage about 8 cm. in diameter. The inner surface was limited to a very thin membrane. The clot within was partially organized and the greatest thickness was 8 mm. The hemorrhage was not attached to the pia and there was no blood staining of the pia over this portion of the brain. There were no fractures of the skull and no contusion or hematomas of the scalp."

A portion of the removed dura with its attached neomembrane was examined and in every respect resembled the lining of a chronic subdural hematoma. The outer lining was opaque and loosely attached to the under surface of the dura from which it could be readily stripped even in the hardened specimen. The inner membrane was very thin and translucent. Portions of the sac are shown in figure 7, which illustrates the gross aspects of the inner and outer surfaces of this membrane, the contents having been removed.

*Comment.*—One is humiliated to confess failure to recognize the lesion in this case, especially as the patient was practically under our constant observation from the time of injury until his death. His mental symptoms were considered partly a consequence of concussion, but more especially as incidental to his advanced age. Reviewing the clinical course in the light of the autopsy, the possibility of a chronic subdural hematoma even in the absence of localizing signs should have been suspected. So far as I have been able to learn this is the only instance in which a traumatic subdural hematoma has been described in a patient of such advanced years.

#### SUMMARY

Cases of chronic subdural hematoma are more frequent than has commonly been supposed. The relatively long period which may elapse from the initial trauma until the development of pressure symptoms frequently leads to overlooking of the injury as a causative factor. While the trauma may be insignificant, this is not always the case, as instances of chronic subdural hematoma may follow severe injuries of the head (cases 5 and 6). The importance of investigating the possible history of preceding trauma in all cases of obscure increasing intracranial pressure should be emphasized.

All cases of chronic subdural hematoma in this series have shown a decidedly high pitched percussion note over the calvarium. In one instance (case 3) an internal hydrocephalus was so strongly suspected because of this sign that lumbar puncture was deferred. The note does not appear to be higher on the side of the hematoma.

The results of the spinal fluid examination vary, depending on the interval which has elapsed since the injury. Practically all cases, regardless of time, show some increase in the spinal fluid pressure. The color at first is usually "smoky" or blood tinged, later becoming yellow, straw colored or perfectly colorless. Instances of each condition have been encountered in this series. There may be an increase in cell count and globulin content of the fluid—or both may be normal.

finally becoming flat. It is supposed that this was caused by edema subsequent to the removal of the hematoma. However, it is doubtful if there was enough edema to demand a decompression as other patients have done as well without it.

*CASE 4.—Chronic subdural hematoma, left side, caused by bumping nose against automobile. Profuse epistaxis, headaches developed several weeks later. In the third month, choked disks and right hemiparesis appeared. Coma. Removal of hematoma; recovery.*

*History.*—J. G., a man, aged 40, married, a civil engineer, referred by Drs. T. C. Lyster and S. D. Ingham of Los Angeles, on May 6, 1924, had a personal history which may have had some bearing on this case, as the patient had been observed twice in sanatoriums because of periods of marked mental depression. One of these periods was about a year before the onset of his present trouble. It is not known whether a diagnosis of any kind of psychosis had been made; a manic-depressive type may have been suspected. The patient was inclined to be morose, introspective and despondent at times, and had done little productive work for several years. About April 1, 1924, while lifting some object in his garage, he slipped forward and struck his nose against his automobile. He was not rendered unconscious, but had a profuse bleeding of the nose which continued intermittently for several days following the injury. About ten days after the injury, he began to have headaches. At first they were not severe and were frontal and bitemporal; later they became more constant and more severe, and he complained particularly of pain back of the eyes and across the forehead. About May 1, a month after the accident, the headaches became so bad that he could hardly endure the pain, and he was unable to sleep. At times he was nauseated and vomited. About this time, he began to notice blurring of vision. He consulted Dr. Lyster. On May 2, a lumbar puncture was performed, which showed the spinal fluid to be under increased pressure and of a light straw color. This tinging of the fluid could be seen best by looking into the depths of the test tube. The fluid contained 5 cells per cubic millimeter, a faint trace of globulin and showed a negative Wassermann reaction. From May 1 to May 6 the patient was observed repeatedly; he was usually lethargic and stuporous, but was well oriented for time, place and person. He complained almost constantly of frontal and bitemporal headaches. The percussion note over the skull was high pitched. An examination of the eyegrounds showed a choked disk of long standing with some embedding of the veins, filling in of the optic cup with new tissue and an occasional fine hemorrhage. There was about 2 diopters swelling on the right side and 3 on the left. The neurologic examination was essentially negative.

*Examination.*—On the morning of May 6, his stupor increased rapidly, and he went into semicoma. A lumbar puncture performed on that date showed the fluid to be under 325 mm. pressure, and still of a pale straw color. About noon, there was evidence of slight weakness of the right side of the face and of the right upper extremity. At this time an increase of the deep reflexes of the right upper and lower extremities was observed. Heretofore they had been normal and equal on both sides. A positive Babinski sign, ankle clonus and Gordon sign developed on the right side; the left remained normal. The abdominal and epigastric reflexes, heretofore normal and equal, showed a decrease on the right side. The patient did not have any convulsions. The blood examination showed hemoglobin, 70 per cent; red blood cells, 4,780,000; white blood cells, 6,201; differential count: polymorphonuclears, 67 per cent; lymphocytes, 30 per cent; eosinophils, 2 per



# Summary of Reported Cases of Subdural Hematoma

Case	Age, Years	Sex	Mode of Injury	Side	Convulsions	Time Elapsed Between Injury and End-Result	Extent of Clot	Assumed Point of Origin	Operative Procedure	Result
1	53	Man	Automobile accident; occipital fracture depressed; unconscious short time	Right	No	Seven months	Frontal, temporal and parietal lobes	Undetermined	Removal small occipital depression in skull; air inflation ventricle; sudden death before attacking hematoma	Dead
2	12	Man	Boxing, black eye; not unconscious; no skull fracture	Left	Yes	One month	Frontal and temporal lobes	Pial vessels near Rolandic and Sylvian fissures	Osteoplastic flap removal. hematoma and meninges	Well
3	13	Boy	Football; not unconscious; no skull fracture	Left	Yes	Six months	Frontal, temporal and parietal lobes	Pial vessels near Sylvian fissures	Osteoplastic flap and decompression; removal hematoma and meninges	Well
4	42	Man	Stumbled and struck nose on automobile; not unconscious; no skull fracture	Left	No	Three months	Frontal and temporal lobes	Undetermined	Osteoplastic flap; removal hematoma and meninges	Well
5	32	Man	Fell 16 feet; unconscious momentarily; no skull fracture	Left	Yes	Five months	Temporal and partly frontal and parietal lobes	Pial vessels; frontal	Osteoplastic flap; removal hematoma and meninges	Well
6	62	Man	Struck by street car; unconscious several hours; linear skull fracture, right frontal	Right	No	Two and a half months	Frontal, temporal and parietal lobes	Undetermined	Decompression; evacuation hematoma; meninges left	Well
7	99	Man	Struck on head by assailant	Left	No	Three months	Frontal lobe	Undetermined	None	Dead



Choked disk is usually present and is frequently more advanced on the side of the hematoma. The elevation of the disks has been found to vary from 1 to 6 diopters in different cases.

Chronic subdural hematoma may occur from childhood to old age. In this series, the ages have varied from 13 to 90. All cases in this series occurred in men. The constancy of the pathologic conditions is surprising, and apparently is not influenced by the age of the patient.

The origin of the hemorrhage in certain instances (cases 2, 3 and 4) seems to be from the pial veins or venous radicals of the longitudinal sinus.

While an osteoplastic flap and removal of the hematoma—both linings and contents, as suggested by Putnam—may be the method of choice, it is felt that such a procedure need not be followed in all cases. It is not unlikely that any operative procedure such as decompression, with evacuation of, or simple trephining and aspiration of the contents of the hematoma—will yield good results. The principle thing after all is to empty the hematoma. When this is accomplished it seldom, if ever, refills, although the fate of the lining membrane is an open question. In the one instance of this series (case 6) in which the lining membranes have been undisturbed except to open and evacuate the clot, the patient's recovery was as prompt as in the others (cases 2, 3, 4 and 5) in which a more extensive operation was performed, and there has not been a tendency to a recurrence of the hematoma.

disk margins appeared to be normal. The cranial nerves throughout appeared normal. It should be stated that for a few days following the operation there was transient diplopia. Coordination was good. The right-sided weakness, which suddenly developed the day of the operation, was gone. All the superficial and deep reflexes were lively and equal. Abnormal reflexes of the Babinski group were not present.

*Comment.*—This patient had exhibited a mental complex, possibly of a mild manic depressive type before his injury. Following the removal of the hematoma and satisfactory recovery from the operation, the mental symptoms continued, probably much the same as before. The localizing signs, as in case 3, came on with remarkable rapidity at the end, in each instance preceded by a violent headache and an increase in stupor. He showed more evidence of postoperative edema than any other patient in this series, even to a rise in temperature and a rapid pulse rate. After removal of several ounces of cerebrospinal fluid, the cerebral balance was again established, and a second episode did not occur.

*CASE 5.*—*Chronic subdural hematoma, left side, caused by falling 18 feet. Immediate symptoms those of slight concussion. Patient returned to work but was forced to stop because of headache. Focal symptoms in the nature of aphasia and jacksonian epilepsy appeared about four months after injury. Removal of hematoma; recovery.*

*History.*—W. G., a man, aged 32, married, referred by Dr. William T. Cade, Jr., of Los Angeles on July 11, 1924, had fallen 18 feet from a derrick on March 22; he was unconscious for about two hours. Bleeding from the ears did not occur, nor was the scalp lacerated. His back was lame for several days. He was unable to work again until April 8; then he "was able to perform some of his duties, but not all," until May 12. On May 10, he began to have a headache, but he continued at work for the next two days. Nausea and vomiting set in on May 12, and by May 14, his pain was intense; his pulse rate was subnormal, from 55 to 60, and his temperature was 97.6 F. He was taken to a hospital in Santa Ana on May 17, where he was studied by Dr. F. E. Coulter. A lumbar puncture, which was performed about this time, showed the spinal fluid to be clear and not under increased pressure. The headache was intermittent, mostly in the right frontal region, but when severe, the pain was all over the calvarium. During the month of June, the patient's symptoms, both subjective and objective, improved, probably because he remained in bed. Localizing signs were not discovered until July. Dr. Coulter, who had him under observation, writes: "On July 10, 1924, about 10:30 a. m., a very different condition was encountered. At the latter date, a history of several spells was obtained, which appeared to be of a jacksonian variety but of the petit mal type. One of these occurred when I was present. In the manifestations observed by me he was wholly unable to speak or answer questions for about one to two minutes. He did not move his right arm or face, and there was no jerking or tremor of any portion of the body observable. A bewildered look was on his face, and I should conclude that full consciousness was absent for the period referred to. In a previous attack occurring two days before he described numbness and tingling as being present in the right forefinger extending to the other fingers of the same hand and up the arm to the shoulder and into the right side of the face. At this time he was unable to talk, and the

# ACTINOMYCOSIS OF THE VERTEBRAE (ACTINOMYCOTIC POTT'S DISEASE)

REPORT OF FOUR CASES \*

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More and more, clinicians and pathologists are becoming convinced that actinomycosis is a common disease. To Sanford and his co-workers <sup>1</sup> is due great credit for their success in pointing out the high incidence of actinomycosis in the United States. In their last two articles they have compiled about 670 cases. Of these, less than one third were found in the literature. Through extensive correspondence, they learned of 334 unpublished cases. To these were added 135 cases from the Mayo Clinic. One can but conclude, then, that actinomycosis in man is much more common than a study of the literature would lead one to believe.

One year after Bollinger of Munich <sup>2</sup> discovered the nature of the disease in cattle afflicted with lumpy-jaw (1877), Israël <sup>3</sup> described the same disease in man. Four years later, Ponfick <sup>4</sup> established the unity of the human and bovine infections. In 1885, John B. Murphy of Chicago <sup>5</sup> described the first American cases.

The first complete study of actinomycosis in this country was carried out by Ruhräh. <sup>6</sup> In 1899 and 1900, he collected the history of sixty-two

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\* From the Pathological Laboratory of the University of Michigan, Ann Arbor, Michigan.

1. Sanford and Voelker: Actinomycosis in the United States, *Arch. Surg.* **11**:809, 1925. Sanford: Distribution of Actinomycosis in the United States, *J. A. M. A.* **81**:655, 1923. Sanford and Magath: The Etiology and Laboratory Diagnosis of Actinomycosis, *Minnesota Med.* **5**:71, 1922.

2. Bollinger: Ueber eine neue Pilzkrankheit beim Rinde, *Centralbl. f. d. med. Wissensch.* **15**:481, 1877.

3. Israël: Neue Beobachtungen auf dem Gebiete der Mykosen des Menschen, *Arch. f. path. Anat.* **74**:15, 1878.

4. Ponfick: Die Actinomykose des Menschen, eine neue Infektionskrankheit auf vergleichend-pathologischer und experimenteller Grundlage geschildert, Berlin, A. Hirschwald, 1882, pp. 138; Ueber eine wahrscheinlich mykotische Form von Wirbelcaries, *Berl. klin. Wchnschr.* **16**:345, 1879; Ueber Aktinomykose, *Berl. klin. Wchnschr.* **17**:660, 1880; *Breslau. aerztl. Ztschr.* **1**:116, 1879.

5. Murphy: Actinomycosis in the Human Subject, *New York M. J.* **41**:17, 1885.

6. Ruhräh: Actinomycosis in Man, with Special Reference to the Cases which Have Been Observed in America, *Ann. Surg.* **30**:417, 605, 722, 1899; **31**:235, 1900.

entire duration of this spell was one to two minutes. This was followed by a severe headache lasting two to three hours. The deep reflexes in both the upper and lower right extremities were found at this time to be less active and to tire more readily than those on the left. This applied to the abnormal reflexes as well. Motor changes in the right extremities were but slightly altered, if at all, from those found in the left."

I observed the patient for ten days before operation, on July 22, at the Good Samaritan Hospital. During this time he was clear and alert mentally. He complained of some headache each day, but the pain was not localized. He was not nauseated and did not vomit. On several occasions there was some confusion in speech when he could not think of the right word. During these short aphasic periods, he complained of numbness of the fingers of the right hand, the numbness extending up the right arm and right side of the face. The right leg was never involved.

*Examination.*—The percussion note over the calvarium was high pitched. The eyeground examination revealed choked disks of long standing, the disk margins being entirely wiped out, the vessels embedded and new tissue obliterating the optic cups. There was an elevation of 4 to 5 diopters, the higher reading being on the left side. The cranial nerves were normal and motor or sensory discrepancies were not observed in any upper or lower extremity. Astereognosis was not present on the right or left. The patient cooperated well on examination; his station was good and his gait normal. The abdominal reflexes were normal and equal. The biceps, triceps, radial and finger reflexes were not exaggerated and seemed to be equal. The knee reflexes were active, the left apparently being more so than the right. At times an ill sustained ankle clonus was present on the right side. Abnormal reflexes of the Babinski group were not shown at any time. Roentgenograms of the skull were taken, and with the exception of some thinning of the posterior clinoids, any pathologic condition was not shown. The spinal fluid again showed a normal pressure, was clear, contained one cell per cubic millimeter and gave a negative butyric and Wassermann reaction. The blood Wassermann reaction was also negative. The blood examination showed the hemoglobin, 77 per cent; color index, 0.93; red blood cells, 4,664,000; white blood cells, 14,400. Urinalysis was negative with the exception of a faint trace of albumin and an occasional hyaline and granular cast.

*Operation and Course.*—A liberal bone flap was turned down on the left side. There was excessive bleeding from the soft tissues and bone. The dura was under increased tension. It was of a pale bluish cast in places and had a feeling almost of fluctuation, especially near the longitudinal sinus (fig. 4). The membrane was first opened over the temporal lobe, liberating an excess of clear spinal fluid, and disclosing a wet, edematous cortex with engorged vessels. A second opening was made through one of these bluish areas in the midparietal region, and the outer wall of a typical encapsulated subdural hemorrhage was encountered. The dural flap was turned back and the "blood cyst" was seen. It extended from the midparietal region up to the longitudinal sinus and forward to the tip of the frontal lobe, covering most of this structure (fig. 5). It did not extend down to the temporal lobe, nor did it cover any part of the occipital lobe. The outer surface of the neomembrane was of a bluish-green mottled appearance, and was loosely adherent to the inner surface of the dura by many fine adhesions. The posterior and lower margins of the hematoma could be studied where it tailed off into the normal cortical surface. There were many fine, spiderweb adhesions running back over the outer surface of the adjacent arachnoid, but the inner membrane was freely movable over the pial surface of the brain. The posterior and

American cases. Clinical interest in this disease in the United States seems to have been first awakened by his thorough studies. In 1902, Erving<sup>7</sup> brought the number of cases up to 100.

In the experience of this laboratory, actinomycosis cannot be considered a rare disease. About thirty cases have been encountered within the past two years. In 1924, Collier and Adie<sup>8</sup> published an excellent preliminary review of fifty cases from this laboratory.

The purpose of this paper is to direct attention to what has been regarded as an exceedingly rare form of the disease, namely, involvement of the vertebrae. Sanford agrees with Luckett,<sup>1</sup> who says that actinomycosis of the bone is rare in man. Bone involvement was not found in the 135 cases from the Mayo Clinic. Among the 670 cases compiled by Sanford, there are but four in which the vertebrae were affected; and of these, two are from the list of fifty-eight Michigan cases supplied by Warthin. These two cases will be dealt with fully in the present paper. The case of spinal actinomycosis casually referred to by McJunkin<sup>9</sup> in the course of a discussion of another case of actinomycosis involving the jaw and cheek is likewise one of the Michigan cases reported by Warthin in Sanford's series. A third case is reported to Sanford by Meyer<sup>10</sup> of Cook County Hospital, Chicago, who tells of a boy, aged 9, who at autopsy showed actinomycosis of both lungs, liver, dorsal vertebrae, periaortic and mesenteric lymph glands. The fourth case was reported by Young,<sup>11</sup> who tells of the extensive involvement of the cervical and thoracic vertebrae, with numerous abscesses, varying from one fourth of an inch to an inch (0.63 to 2.5 cm.) in diameter. The tenth dorsal vertebra was denuded of periosteum and communicated with a large abscess cavity. The spinous processes of the lower dorsal vertebrae contained many ray fungi.

Bassoe of Chicago,<sup>12</sup> in discussing one of Sanford's papers, mentions two cases of spinal actinomycosis. The first was in a young man, and had been diagnosed tuberculosis by many physicians. Subsequent roentgen-ray examination showed erosion of the heads of the ribs, and the diagnosis was changed to malignant tumor. Vertebral abscesses formed, but the diagnosis was established at autopsy. In the second of

7. Erving: *Actinomycosis Hominis in America*, with Report of Six Cases, *Bull. Johns Hopkins Hosp.* **13**:261, 1902.

8. Collier and Adie: *Actinomycosis in Man*, *J. Michigan M. Soc.* **23**:366, 1924.

9. McJunkin: *A Case of Infection with Actinomycosis Bovis*, *Physician & Surgeon*, Ann Arbor and Detroit **29**:213, 1907.

10. Meyer: *Communication to Sanford*, *Arch. Surg.* **11**:824, 1925.

11. Young: *Actinomycosis of the Ribs and Vertebrae*, *Am. J. Orthopedic Surg.* **6**:252, 1908-1909.

12. Bassoe: *Discussion of Sanford's Article*, *J. A. M. A.* **81**:655 (Aug. 25) 1923.

inferior margins could be rolled away from the brain with a blunt dissector and the fingers. The outer wall of the clot was opened, and an abundance of dark greenish fluid and a large mass of blood clot were removed. As in other cases, the outer lining was about 2 mm. thick and opaque, while the inner surface was much thinner, translucent and could be moved over the underlying cortex with the fingers (fig. 6). The clot was about 4 cm. thick in the parietal and midfrontal region, and the underlying brain showed marked depression where the hematoma had lain on it. In dissecting the membrane from the frontal region, sharp bleeding was encountered far forward. This was controlled by temporary packing with cotton, which was removed subsequently, leaving a dry field before closure. The middle meningeal artery was intact, and the lining membrane of the hematoma was not unduly adherent, except far forward in the frontal region. It was assumed that the hemorrhage originated from the pial vessels or radicals of the longitudinal sinus in the frontal region, although this was not accurately determined. The under surface of the dura oozed considerably after the underlying hematoma was stripped from it. The dura was closed, a folded gutta-percha drain being placed under it to provide adequate drainage, as the operator was not satisfied with the dryness of the field on closure. The procedure lasted three hours, and the patient left the table in fairly good condition.

He made a satisfactory convalescence and left the hospital on August 24. There was free drainage for about a week following the operation, but the bone flap never became elevated as it did in cases 2 and 3. Aphasia or jacksonian episodes did not return. His eyegrounds became flat in a few weeks, and the headache disappeared to a great extent. Strange to say, he complained of a sharp pain in the right frontal region for many weeks following the operation. This persisted intermittently and with decreasing frequency and intensity for almost a year. He returned to work as a fireman in the oil fields on Sept. 22, 1924, and has been working constantly.

*Comment.*—In this instance there is a history of more severe injury of the head than in the other cases reported. The man fell 18 feet, became unconscious immediately and remained so for two hours. He attempted to return to work the next day, but was unable to continue, not because of headache but because of lameness in his back. He worked from April 8 to May 12, when he was forced to stop because of headache. For the next two months, localizing signs were not seen, and then suddenly there were periods of aphasia with numbness of the right hand. The hematoma in this case was high up near the longitudinal sinus, and gave rise to the question whether it did not come from the venous radicals of this structure, as suggested by Trotter. The presence of a rather severe frontal headache on the right side following the operation raised the query whether there might have been a second hematoma over the right frontal lobe arising from the radicals of the sinus on that side.

*CASE 6.*—*Chronic subdural hematoma right side; occasioned by fractured skull. Immediate symptoms mild and cleared up. Discharged from hospital in satisfactory condition, three weeks after injury, to return six weeks later in coma. Operation ten weeks after injury revealed hematoma which was simply drained. Surrounding membranes of hematoma not removed. Recovery.*





March 28, 1912. He had been confined to his bed for two or three weeks, suffering severe pain. Physical examination at that time showed a markedly emaciated and cachectic man. Examination of the left femur showed a fusiform enlargement occupying the whole upper half of the thigh, the largest circumference measuring 22 inches (55.5 cm.). The tumor extended well beyond Poupert's ligament anteriorly, and posteriorly above the trochanter. The joint apparently



Fig. 57 (case 122 in table 7).—Three weeks later than figure 56.

was not involved, and there were no glands in the groin. The skin was not adherent, but was of a purplish color, due to a large amount of delayed venous blood. There was no evidence of metastasis. The patient was admitted to the Memorial Hospital, March 31, 1912; on the day following a hip joint amputation was performed by one of us (W. B. C.); the growth extended so high up that after the leg was removed the muscular tissue retracted up to it. Although there was little hemorrhage, the patient's general condition was extremely bad, and

when the operation was completed he was practically pulseless. He was given 4 ounces (118.4 cc.) of black coffee and whisky by rectum, and on reaching the ward, 1,000 cm. of salt solution intravenously. He rallied shortly afterward and was in good condition on the following morning.

The microscopic report of Ewing was: "The myxochondrosarcoma with the cartilage is almost completely degenerated into mucous tissue; there is some well defined embryonal cartilage."

The mixed toxins were begun as soon as the patient had recovered from the operation, and were continued for three months. His general condition improved steadily; he was shown before the Clinical Congress of Surgeons of North America in November, 1912, at which time he was in excellent condition without any trace of a recurrence; he had gained 30 pounds (13.6 Kg.) in weight. At the time of my last examination, three years later, he was still in perfect health.

CASE 32 (Dr. George B. Packard, Jr., Denver).—*Sarcoma of upper third of femur; inoperable (clinical and roentgen-ray diagnosis); recovery under toxins; patient well five years later; probably endothelioma.*

G. M., a boy, aged 9 years, in the latter part of 1919 fell on a hard floor, shortly after which a swelling developed in the upper third of the left femur and grew rapidly; this was accompanied by a great deal of pain and considerable loss of flesh and strength. A roentgenogram taken at the time of the injury showed no pathologic lesion. The patient came under the care of Dr. G. B. Packard four months later. Roentgen-ray examination by Dr. Brandenburg, Jan. 2, 1920, showed general bone destruction involving the head, neck and trochanter of the femur with a complete pathologic fracture of the neck close to the head. The diagnosis was osteosarcoma. Dr. Packard stated that the patient's condition was too poor to warrant even an exploratory operation; he had been bedridden for three months, was markedly emaciated, and had two huge sloughing ulcers on his back.

January 6, he was placed on the mixed toxins of erysipelas and *Bacillus prodigiosus*, beginning with a dose of 0.01 cc., increasing gradually to 0.8 cc. (the highest dose). He received almost daily injections, 119 in all being given up to October 23; the highest reaction obtained was 104 F. The patient showed almost immediate and steady improvement. By March 1 the pain had entirely ceased, he had a good appetite, had gained considerable weight, and was up and about in a wheel chair. There was no great change in the size of the tumor, but the edema and prominent veins had disappeared and the bed sores were healed. By April 25, the general appearance of the patient was excellent; he had no pain, and the tumor had decreased somewhat in size. By June 15 he was able to walk with crutches. By August 15 he was still unable to lift the extended leg in bed (probably a nonunion following tumor absorption). Roentgen-ray examination, September 2, showed: "The sarcoma has involved the upper end of the femur, the trochanters, the neck and head of the femur, and slightly the acetabulum, with almost complete destruction of the head and neck and considerable destruction of the trochanters. There is no evidence of union. There is good healing and the beginning of an attempt at repair." The new bone formation apparently continued; there was complete restoration of function, the pathologic fracture reunited, and the patient was in excellent condition in November, 1925, with no evidence of a recurrence, five years later.

We have been in close touch with Dr. Packard in the treatment of this patient, and he has given me the roentgenogram taken immediately after the injury as well as other pictures taken after the tumor had developed. While no microscopic examination was made in this case, we believe that the clinical history and

surrounding almost the entire lumbar spine and extending downward in either psoas muscle to the inguinal region. The sides of the bodies and transverse processes of the vertebrae were extensively eroded and covered by pus and granulation tissue. The erosive process extended into the bodies, and a large granuloma had formed between the posterior surface of the bodies and the outside of the dura, compressing the cauda equina. Ray fungi were found on microscopic examination of tissue.

Abbott of Chicago<sup>18</sup> describes what he considers to be a case of primary actinomycosis of the left kidney in a woman, aged 43. The patient died soon after operation. At autopsy, a large abscess was found behind an enormously large kidney, which involved the muscles of the posterior abdominal wall and the fourth and fifth lumbar vertebrae. The process had extended into the spinal canal and involved the spinal cord externally. A left-sided psoas abscess communicated with the retro-nephritic abscess. Brickner<sup>19</sup> mentions a case of actinomycosis of the cervical spine, neck and back in a boy.

In foreign literature, the cases of Ponfick,<sup>4</sup> Boström,<sup>20</sup> Ginsberg (two cases),<sup>21</sup> Kolacek,<sup>22</sup> Guleke,<sup>23</sup> Patterson and Natrass,<sup>24</sup> Heuck,<sup>25</sup> Godlee (three cases),<sup>26</sup> Martens,<sup>27</sup> Chauffard and Troisier,<sup>28</sup> Macaigne and Raingeard,<sup>29</sup> Garten<sup>30</sup> and Cope<sup>31</sup> present the same pathologic characteristics as the American cases previously described.

To these twenty-eight cases we would like to add four from our own experience. Two of our cases have been encountered within the past

19. Brickner: Pelvic Actinomycosis, *Ann. Surg.* **81**:343, 1925.

20. Boström: Untersuchungen ueber die Aktinomykose des Menschen, *Beitr. z. path. Anat. u. z. allg. Pathol.* **9**:1, 1891.

21. Ginsberg: Casuistische Beiträge zur Kenntniss der Actinomycose der Menschen, Berlin, G. Chasté, 1890, p. 30.

22. Kolacek: Ueber aktinomykotische Allgemeininfektion, *Beitr. z. klin. Chir.* **93**:136, 1914.

23. Guleke: Zwei seltenere Wirbelerkrankungen (Echinococcus und Aktinomykose), *Deutsch. Ztschr. f. Chir.* **162**:59, 1921.

24. Patterson and Natrass: Actinomycosis of the Pleura, *Brit. M. J.* **1**:918, 1925.

25. Heuck: Ein Fall von Aktinomykose der Wirbelsäule und Brustwandungen mit Propagation auf die Lunge, *München. med. Wchnschr.* **39**:419, 1892.

26. Godlee: A Series of Cases of Actinomycosis, *Lancet* **1**:3, 1901.

27. Martens: Zur Kenntniss der Lungen- und Wirbelsäulenaktinomykose, *Arch. f. klin. Chir.* **66**:698, 1902.

28. Chauffard and Troisier: Actinomycome cervico-rachidien, *Rev. de méd.* **29**:753, 1909.

29. Macaigne and Raingeard: Actinomycome thoracique, cutanée, vertébrale, pulmonaire; etude anatomique, *Presse méd.* **1**:331, 1898.

30. Garten: Ueber einen beim Menschen chronische Eiterung erregenden pleomorphen Mikroben, *Deutsche Ztschr. f. Chir.* **41**:257, 1895.

31. Cope: A Clinical Study of Actinomycosis with Illustrative Cases, *Brit. J. Surg.* **3**:55, 1915-1916.

abscesses and fistulous tracts lined by typical actinomycotic granulation tissue and containing numerous ray fungi. Multiple small abscesses in loose tissues were found about the seminal vesicles. Multiple small chronic abscesses, rich in old and young repair tissue, with many lipoid cells, and numerous large colonies of actinomyces appeared in the right perinephritic tissues.

*Pathologic Diagnosis.*—The diagnosis was: chronic actinomycosis, probably primary in the appendix, with multiple abscesses and sinus tracts involving the right abdominal wall, the liver, the first, second and third lumbar vertebrae, the right psoas muscle, the right perinephritic tissue, the lower right intercostal muscles, the right tenth rib, the seminal vesicles and the scrotum; chronic productive peritonitis, with recent purulent exacerbation; chronic adhesive pleuritis on the right side; pulmonary edema; early chronic glomerulotubular nephritis; fatty degenerative infiltration of the liver and the heart; fatty infiltration of the liver; localized myocardial fibrosis; adenomatous colloid goiter; moderate atherosclerosis of the aorta and the coronary arteries; atrophy, passive congestion and marked parenchymatous degeneration of all organs; mucoid atrophy of all adipose tissue; cachexia; aspermatogenesis.

#### COMMENT

'It is important to emphasize that the clinical diagnosis in each of our four cases was tuberculosis of the spine (Pott's disease). The clinical distinction between tuberculosis and actinomycosis of the spine presents many difficulties. In analyzing the data from the four cases which we have studied, we have arrived at certain conclusions which may be of help in reaching a proper diagnosis.

Great aid is to be derived from roentgenologic studies. The characteristic pathologic anatomy of actinomycosis of the vertebrae is erosion of the cortical portion of the bone. It usually affects the vertebrae first as a periostitis, as the result of direct extension of a paravertebral phlegmon which has had its origin in the lungs or intestinal tract. The periosteum becomes elevated by the spreading sinuses and abscesses, and the cortex of the bone is attacked. Pulmonary actinomycosis is characterized by multiple abscesses and burrowing sinus channels which soon reach the pleura, with resultant adhesive pleuritis and localized empyema pockets, which either burrow their way through the intercostal spaces or extend up and down along the vertebral column as a paravertebral phlegmon. In intestinal actinomycosis, most frequently primary in the appendix, the abscesses soon affect the retroperitoneal tissues and spread along the lumbar vertebrae and establish psoas abscesses, or gain access to the surface of the body by the establishment of numerous sinus tracts elsewhere. In our second case the pointing of the psoas abscess was the first symptom and sign.

In tuberculosis, on the other hand, the destruction of the vertebrae chiefly affects first the inner part of the body, usually near an intervertebral disk, ultimately destroying the whole body, and permitting collapse and the characteristic angular deformity. Such central and complete destruction with the development of kyphosis is not a feature of

year. Certainly, the evidence that five of the thirteen American cases previously reported have been reported by Chicago physicians, and that the University of Michigan Pathological Laboratory has had such a wide experience in this type of case, constitutes presumptive proof that spinal actinomycosis is not uncommon.

Abstracts of the clinical records and autopsy protocols follow :

**CASE 1.—History.**—G. H., aged 30, an American, a stonecutter, had a condition diagnosed as sepsis, bilateral empyema, putrid bronchitis, generalized tuberculosis and meningitis (?). (No other record was available.)

**Autopsy.**—(Prosector, Dr. A. S. Warthin.) The body was that of a slender, emaciated young man. The fingers were slightly clubbed. In the left posterior axillary line were two openings, both of which were partially covered with bloody crusts, but each of which yielded seropurulent discharge on pressure.

The left lung adhered firmly to the wall of the chest. From the sixth rib down to the base there was an encapsulated cavity in the posterior axillary region, surrounded by firm adhesions. This was filled with thick, creamy, blood-stained pus. The upper lobe was voluminous, the lower atelectatic. Many small whitish spots were visible beneath the pleura, and were firm in consistency. The right lung was likewise bound by firm adhesions, most marked posteriorly, from the fourth rib to the base. The borders of the lung were somewhat emphysematous, and the lower lobe was atelectatic. The pleura was greatly thickened, dense and hyaline in places, and covered with stringy, thickened masses of organized fibrin. Small whitish areas were present in the granulation tissue. On section the upper lobe showed marked edema. The smaller bronchi were somewhat dilated. Small areas of pus were encountered in and around the bronchi; abundant exudate was expressed on pressure. In the middle lobe was a small encapsulated cavity containing thick yellow pus.

Extending from the eighth dorsal vertebra downward to the second lumbar, the fascia and muscles on both sides were infiltrated with thick pus, involving both psoas muscles. When the psoas muscles were cut on each side, they were found to be infiltrated with pus. At the level of the eleventh dorsal vertebra on the left side, a sinus tract was found to extend between the vertebral laminae into the spinal canal. The spinous processes of the lower four dorsal vertebrae showed considerable superficial erosion. At this site pus bathed the dura posteriorly, though the cord was not affected. The surfaces of the tenth and eleventh vertebrae bordering the canal were eroded, and the purulent process extended deeply into the cancellous tissue of the vertebrae.

**Microscopic Observations.**—The lungs showed chronic abscesses of varying age. In all cavities were numerous colonies of *Actinomyces*, surrounded by areas of purulent pneumonia, showing varying degrees of organization. Chronic purulent bronchitis was also found. The bronchial lymph glands showed numerous abscesses, with many colonies of *Actinomyces*. Purulent pachymeningitis externa, with many ray fungi, had affected the thoracic spinal cord. Purulent osteomyelitis was present in the vertebrae, with multiple abscesses of cancellous bone and numerous ray fungi. Amyloid deposits were found in the spleen.

**Pathologic Diagnosis.**—The diagnosis was: actinomycosis of lungs and dorsal and lumbar vertebrae, with bilateral psoas abscesses; purulent pachymeningitis externa; empyema; chronic glomerulotubular nephritis; amyloidosis of the spleen; atrophy, passive congestion and marked parenchymatous degeneration of all organs.

actinomycosis of the vertebrae. In tuberculosis, likewise, the laminae, articular facets, transverse processes and spinous processes are almost always preserved, while in actinomycosis they show the same erosion as the bodies. Such was the case in three of our four cases. This anatomic peculiarity at once possesses great roentgenologic significance. Tuberculosis of the spine is primarily a disease of the interior of the body; actinomycosis does not show such sharp selectivity.

One common source of error is the almost instinctive association of psoas abscesses with tuberculosis of the spine. Actinomycosis, syphilis or neoplasm of the spine, particularly if secondary, periappendiceal abscesses, perinephritic abscesses, retroperitoneal abscesses and pelvic abscesses often extend along the iliopsoas muscle and fascia, and give rise to psoas abscesses indistinguishable from the so-called "cold abscesses" of tuberculosis of the spine. In actinomycosis, abscesses and sinus tracts are usually multiple, or a single large sinus tract may have many ostia.

As the sinus tract dissects its way toward the surface of the skin, the subcutaneous tissues become indurated, and purplish or purplish-red plaques appear on the surface. These gradually soften toward the center, become definitely fluctuant and finally break through the skin. The boardlike, painless or slightly painful induration, with multiple abscesses and sinus tracts, is a prominent characteristic. It is at this time that the pathognomonic ray fungi, in the form of the so-called "sulphur granules," are most likely to be found. The sinus soon becomes secondarily infected, and the inevitable pyogenic process obscures the actinomycotic granulations. The first pus to escape is usually thick, and in our cases was described as being "creamy yellow," and was often blood-stained. The pus of actinomycosis is said to have a distinctive odor, similar to that of freshly turned soil—an "earthy" odor. If the sinus is drained surgically, it is desirable for the surgeon to examine the pus carefully for the sulphur granules at the time of evacuation. The simplest way is to place a thin smear of any suspicious looking material on a glass slide and crush by gentle pressure on a cover-slip any granules which might prove to be ray fungi. A little 5 per cent potassium hydroxide solution may be run in under the cover-glass if the pus is thick. Staining is not necessary, as the characteristic central densely interwoven feltwork of mycelial filaments and the highly refractive radiating peripheral clubs can easily be recognized with the low power objective of the microscope. When the pus is abundant, the dilution method suggested by Da Costa<sup>33</sup> and Colebrook<sup>34</sup> might be tried.

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33. Da Costa: Actinomycosis, *Ann. Surg.* 54:130, 1911.

34. Colebrook: A Report upon 25 Cases of Actinomycosis with Especial Reference to Vaccine Therapy, *Lancet* 1:893, 1921.

CASE 2.—*History*.—J. M., a white man, aged 42, a carpenter, who was admitted to the University of Michigan Hospital on Feb. 26, 1922, complained of pain and swelling in the left flank and groin. His family history and past history were negative. In August, 1921, the patient had severe, cramplike pain in the lower part of the abdomen which radiated to the rectum. Three or four days later he suffered from chills, and a sensation of choking was experienced. In two weeks, pain occurred in the left side of the abdomen, which increased so that in September he was forced to take to his bed. A swelling began in the left inguinal region. It became reddened, hot and tender. Pain was then experienced in the left hip, and a flexion contracture gradually developed. Great pain was caused by extending the left lower extremity. He had lost 10 pounds (4.5 Kg.) in weight in six months. He had an occasional cough and profuse night sweats, with chills and fever.

*Physical Examination*.—Beyond the observation of severe emaciation, the results of the examination were practically negative except for the local process. Over the left anterior superior iliac spine and inguinal ligament, there was a swelling about 2 inches (5 cm.) long and 1 inch (2.5 cm.) broad, that was raised above the surrounding surface about half an inch (1.27 cm.). It was tender and reddened, but not definitely fluctuant. Palpation of the abdomen revealed some resistance in the left lower quadrant. The left thigh was flexed nearly to a right angle and could be extended to about 160 degrees. There was considerable pain on movement of the joint.

Roentgen-ray examination of the chest did not reveal positive signs of disease. There was some haziness about the apexes, which were regarded as the only likely areas of involvement. The lumbar vertebrae showed superficial destruction and loss of detail around the articular facets of the fifth lumbar vertebra, without loss of the joint space, however. The patient was thought to have a tuberculous process of the fifth lumbar vertebra.

Two weeks after the patient was admitted, the abscess was opened. It drained freely. The patient's condition gradually grew worse. Drainage was reestablished on March 23. The next day material similar to feces escaped from the wound, and on March 26 he had a severe hemorrhage from the sinus. Three days later he died.

The clinical diagnosis was Pott's disease with psoas abscess.

*Autopsy*.—(Prosector, Dr. C. V. Weller.) The body was that of a poorly nourished male adult. About 2 cm. below the anterior superior iliac spine on the left was a sinus-opening that measured 2 by 3 cm., having a firm, elevated, brownish-red border and a discolored, necrotic wall, from the mouth of which a small amount of thin seropurulent fluid escaped. This opened into a large cavity occupying part of the concavity of the left ilium, and extended toward the left psoas muscle.

The lungs were somewhat adherent, and on section showed congestion and edema. Beneath the visceral pleura each lung showed several firm hemorrhagic and yellowish purulent areas.

The abdominal examination revealed firm adhesions about the appendix and the descending colon. The former, at the junction of the middle and distal thirds, was dilated and greenish black. Here it was in immediate relationship with a small abscess cavity included beneath the adhesions which covered the appendix and bound it down to the sheath of the psoas muscle. On freeing this area from the psoas sheath and the vertebral fascia, purulent exudate appeared along the sides of the lumbar vertebrae. The descending colon was firmly adherent over an abscess cavity that involved the left iliopsoas muscle. At this point the colonic wall appeared discolored and necrotic, and showed some purulent infiltration.



Several drops of pus are collected in a test tube half filled with water. After corking, the tube is vigorously shaken for a few moments. This emulsifies the pus and does not break up the firm granules. These sink to the bottom of the tube, where they can easily be recognized and picked up with a capillary pipet, after which they can be lightly crushed between a slide and cover-slip and examined microscopically while fresh. Another simple procedure is to spread the pus in a thin layer on a glass plate over a dark background. When included in the mass of pus which appears on surgical evacuation, the yellowish or grayish-yellow bodies are often distinguished with difficulty. It is, therefore, wise to carry out some such simple procedure as that outlined above.

The granules are not always a sulphur yellow, but may be gray, white, yellow-brown or even green. The younger ones are much smaller than the head of a common pin and are usually silvery gray. Because of these variations in color, small caseous plugs from tuberculous sinuses or even the small epithelial pearls of infected squamous cell carcinoma may grossly simulate ray fungi. Differentiation is easily made with the microscope. The older granules vary in size, but are usually somewhat larger than the head of a common pin and are most often yellowish or yellowish white.

The pus should be examined carefully and repeatedly for the presence or absence of tubercle bacilli if ray fungi are not found. The persistent absence of tubercle bacilli should always stimulate one to examine further for the ray fungus.

It not infrequently happens that repeated examination of the pus does not reveal tubercle bacilli or ray fungi. Curettement of the granulation tissue lining of the sinus tract, with histopathologic examination of the fragments, will often settle the question. At this point it might be well to emphasize that the granulation tissue of actinomycosis has certain characteristics which, while not pathognomonic in the absence of the actinomycotic colonies, serve to focus the microscopist's attention on this disease. The vascular pyogenic granulation tissue almost invariably contains many pale, vacuolated lipid-containing cells that are almost never found in conjunction with simple tuberculous. Then, again, as the actinomycotic process burrows its way through the soft tissues, usually through connective tissue and along fascial planes, the often lesions have a tendency to heal partially, and much firm, glistering, connective tissue hyalin is developed. This ordinarily assumes a honey-combed or lobulated appearance with firm connective tissue septa separating small abscesses, in the centers of which the ray fungus is usually found, surrounded by pus cells and a zone of this peculiar light granulation tissue. The finding of this combination of light granulation tissue and the honey-combed pattern of dense connective tissue septa suggests the possibility of more solid sections in the further exam-

The left psoas muscle was the site of an extensive purulent infiltration, characterized by multiple burrowing, fistulous tracts and larger abscess cavities, all containing thick, creamy yellow pus. Similar purulent infiltrations extended into the iliacus muscle, which, however, was for the greater part converted into a single large abscess cavity opening below the anterior superior iliac spine as previously described. The right psoas muscle was infiltrated with creamy yellowish purulent exudate, especially in the area of its vertebral attachment.

The bodies and laminae of the vertebrae in the entire lumbar region were honeycombed with purulent sinus tracts which were a dirty, greenish black. There was extensive necrosis. The peripheral portion of the vertebral bodies could be cut readily with the cartilage knife. This condition became less extensive in the bodies of the vertebrae of the lower thoracic region, but here the purulent sinus tracts extended, especially along the periosteal surfaces, with multiple small abscesses in the peripheral portions of the bodies. Purulent material from these sinuses was found to contain soft, spherical, grayish-white or yellowish-gray granules. One of these when crushed and examined under the microscope revealed many pus cells and typical colonies of *Actinomyces*. The spinal dura in the sacral region was covered with a purulent exudate on its outer surface. The cerebrospinal fluid was clear. The inner meninges and the cord itself showed congestion only.

*Microscopic Observations.*—The spinal cord showed organizing pachymeningitis externa, with numerous abscesses and ray fungi. In the lungs were recent hemorrhagic infarcts, streptococcus emboli and passive congestion.

Chronic recurrent appendicitis was shown by marked induration of the wall of the appendix and periappendiceal induration, containing old purulent tracts. Psoas abscesses contained purulent sinus tracts, numerous colonies of streptococci and colonies of *Actinomyces*. There was marked regeneration of muscle. Marked purulent osteomyelitis was shown in the vertebrae. There were multiple abscesses containing colonies of *Actinomyces*.

*Pathologic Diagnosis.*—The diagnosis was: actinomycosis of the lumbar and lower thoracic vertebrae, with extension to the psoas muscle on the left side, perforating below Poupart's ligament; localized right psoas abscess (actinomycotic Pott's disease); organizing purulent pachymeningitis externa; multiple recent actinomycotic abscesses in the lungs; secondary streptococcus infection; multiple streptococcus emboli in all organs and tissues; multiple hemorrhagic infarctions of the lungs; atrophy, passive congestion, and parenchymatous degeneration of all organs; nutmeg liver; chronic catarrhal appendicitis; general marasmus; decubitus.

*CASE 3.—History.*—A. D., a Finnish lumberman, aged 50, entered the hospital on Oct. 3, 1925. The details of his illness were hard to obtain because of linguistic difficulties. He had come to this country twenty-five years before and had worked most of his adult life in the woods of northern Michigan. His health had always been good until the winter of 1924-1925, when he had injured his back as the result of a fall. He had never regained his proper strength after the accident, and was forced to retire early in the evening and to do less work during the day. He complained of pains in his chest and back, but refused to consult a physician. The loss of weight, strength and energy finally forced him to visit a physician in the spring of 1925, and he was later advised to come to the University of Michigan Hospital.

*Physical Examination.*—The patient was moderately emaciated and appeared anemic. He looked decidedly ill and as if he were in the terminal stages of a

for the ray fungus. At all events, the discovery of the lipid granulations throws the weight of evidence in favor of a diagnosis of actinomycosis, even in the absence of the pathognomonic ray fungus.

Coller and Adie<sup>8</sup> have found that the bleeding during and following the surgical drainage of actinomycotic abscesses is much more profuse than that which accompanies the drainage of tuberculous or simple pyogenic abscesses. This rather constant observation has led them to attach diagnostic importance to it. In case 2 of our series an exsanguinating hemorrhage from a psoas abscess which had been surgically drained the day before was the immediate cause of death. Frequent reference to the vascularity of actinomycotic granulation tissue as contrasted with the relative avascularity of tuberculous granulations is to be found in the literature.

The splenic amyloidosis in case 1 is of more than passing interest because of its great rarity in association with actinomycosis. In the presence of such extensive chronic suppuration, with secondary pyogenic infection, as characterizes most cases of advanced chronic actinomycosis, it is rather to be wondered at that amyloidosis is not more common.

In the first three cases, actinomycotic pachymeningitis externa was a prominent anatomic observation. In each instance, the small abscesses and organizing exudate on the outer dural surface obviously were the result of direct extension of the paravertebral actinomycotic phlegmon through the bodies and laminae and intervertebral foramina to the spinal canal. There was not in any case clinical evidence of pressure on the spinal roots or spinal cord. This is, on the other hand, not uncommon in tuberculosis of the spine.

#### ORIGIN AND MANNER OF SPREAD

As the literature on actinomycosis in this country accumulates, one is more and more at a loss to account for the mechanism by which this disease establishes itself. The older belief that actinomycosis is primarily a disease of persons who live in rural communities and who have had intimate contact with cattle affected with "lumpy jaw," or that man acquires it in the same way as cattle, by chewing grass, straw, grains, etc., is practically invalidated by the fact that fully one half of the American cases do not have such a history. Occupation as an etiologic factor assumes little importance in our four cases, since three of the four patients were engaged in nonagricultural pursuits.

One cannot but be impressed by Wright's conclusions after his exhaustive experimental studies:

Because the micro-organism does not grow well on all the ordinary culture media and practically not at all at room temperature, I do not believe that it has its usual habitat outside of the body. It seems to be very probable that *Actinomycosis bovis* is a normal inhabitant . . . of the buccal cavity and of the gastro-intestinal tract, both of men and animals. . . .

chronic malady. He had a slight diffuse swelling in the upper dorsal region. Some tenderness and possible slight fluctuation were found on deep pressure over this area. The lungs showed some dulness, with fine moist râles, most marked on the right. Roentgen-ray studies of the lungs did not reveal definite evidence of a parenchymatous lesion, but the hilum glands on the right side were somewhat enlarged. Stereoscopic study of the dorsal spine showed an increase in the curve in the upper dorsal region, with widening of the soft shadows about the vertebrae. There was marked haziness of the fourth, fifth and sixth vertebrae with apparent loss of the intervertebral space between the fifth and sixth, and sixth and seventh. The roentgenologist's diagnosis was tuberculosis of the spine with abscess formation.

The abscess between the scapulae was aspirated, and thick, yellowish purulent matter was obtained. Gross examination failed to show "sulphur granules." Two small sinuses formed in the interscapular region which continued to drain until the patient's death. During his stay in the hospital the patient ran an intermittent fever reaching 101 F. practically every afternoon. His pulse rate was constantly elevated, generally between 90 and 100 beats a minute.

The patient's strength gradually failed, and on Dec. 28, 1925, he died. The clinical diagnosis was pulmonary tuberculosis and advanced Pott's disease.

*Autopsy.*—(Prosectors, Drs. Simpson and McIntosh.) The body was that of a short, emaciated white man. Between the scapulae there was a large, irregularly oval, fluctuant mass which measured 14 cm. in diameter. Its upper border was at the level of the second thoracic vertebra. It measured 5 or 6 cm. in width and began in the midline above, but extended somewhat to the left inferiorly. The mass rose 1 or 2 cm. above the skin surface. It was thin walled, soft, and on pressure, thick, purulent, hemorrhagic material was expressed through two small openings, one on each side of the midline. They were situated from 5 to 7 cm. below the abscess cavity, and communicated with it by sinus tracts. The spinous processes of the third, fourth, fifth and sixth dorsal vertebrae could not be palpated through the fluctuant area. The remaining dorsal spines were readily felt. The cadaver appeared anemic, and showed emaciation, but jaundice was not present.

When the spinal column was examined, it was found that the bodies of the vertebrae, from the seventh cervical to the ninth dorsal, were involved in a chronic purulent process. There was only a slight peripheral loss of substance of the vertebrae. The vertebral bodies, laminae and intervertebral disks were coated with thick granulation tissue, interspersed with pockets of fibrinopurulent exudate. The spinous processes of the third, fourth, fifth and sixth dorsal vertebrae were bathed in pus and showed varying degrees of superficial erosion. The outer surface of the spinal dura was much thickened, and was covered for the most part by organizing fibrinopurulent exudate. The inner meninges showed little change. The cord showed no abnormality.

The left lung was everywhere adherent to the parietes. In its upper and posterior portion there were multiple localized collections of pus between the firm fibrous pleural adhesions. The pleura was greatly thickened, partly by fibrinous exudate and partly by hyalinized connective tissue. On section the fibrous tissue elements of the lung were greatly increased. There was considerable purulent matter in the bronchi and smaller bronchioles. Here and there small pale areas were seen in the parenchyma, and others slightly larger that were definitely minute abscess cavities.

The right lung was larger than the left, but otherwise they were similar. There were the same pleural adhesions and areas of encapsulated empyema. A cut

The factor of injury to mucosae, plus susceptibility, unquestionably plays a major part. Against such a thesis, of course, is the infrequency with which true *Actinomyces* is found in the crypts of the tonsil during the course of routine histopathologic examinations. In all probability, most of the so-called tonsillar actinomycetes are actually colonies of harmless mouth organisms which frequently simulate the asteroid configuration, staining reactions and size of true *Actinomyces*. Then, too, if Wright's theory is entirely correct, the ray fungus should be found in gastric and intestinal contents examined during life and postmortem.

In cases 1 and 3, the disease was obviously primary in the lungs, with direct extension to the pleura. Organizing adhesive pleuritis is an almost constant observation in such cases, with abscesses, sinus tracts and encapsulated empyema pockets. The spread of the disease to the intercostal spaces, ribs and vertebrae is then the result of contiguous extension.

In cases 2 and 4, the disease apparently had its origin in the appendix, with the development of retroperitoneal abscesses and sinus tracts and direct communication by contiguity with the paravertebral tissues. Actinomycosis of the appendix and cecum is common, ranking next in order of frequency to cervicofacial actinomycosis. The onset frequently simulates that of the ordinary acute pyogenic process. Following appendectomy or the drainage of a periappendiceal abscess, a discharging sinus develops, which resists all ordinary forms of treatment. In such cases, actinomycosis should always be considered.

Most writers have stated that actinomycosis rarely, if ever, affects lymphoid tissue. The statement that involvement of the bone and lymph glands is extremely rare in actinomycosis and is common in tuberculosis needs some revision as regards the actinomycosis. In our experience, involvement of bone has been common, while in two of the four cases included in this report (cases 2 and 3), the bronchial lymph nodes were the site of multiple abscesses containing many colonies.

Hematogenous metastasis unquestionably occurs, as is shown by the cases in our series in which solitary renal or cerebral or hepatic abscesses have been found, with the primary focus in the intestines or lungs. But by far the most important manner of spread is by direct contiguity, by means of burrowing sinus tracts, almost invariably multiple, frequently branching and anastomosing, and ultimately reaching the surface. The multiplicity of the sinuses, the brawny induration of the surrounding tissues and the persistent absence of the tubercle bacillus, should direct one's thoughts toward actinomycosis, even in the absence of the "sulphur bodies." The finding of the lipid granulation tissue on histologic examination lends further support. Of course, the presence of the ray fungus fixes the diagnosis, but even with repeated searches it frequently cannot be found. Brickner<sup>19</sup> regards the long

section revealed an old fibroid pneumonia of the upper lobe, but abscess cavities were not present. There was likewise purulent bronchitis and bronchopneumonia. After removal of the left lung, pressure on the fluctuant tumor mass between the scapulae caused the escape of thick sanguinopurulent material into the cavity of the chest by multiple sinus tracts that opened in the intercostal spaces. Some of these extended along the sides of the vertebral bodies.

Within the small intestine in its upper portion were two intestinal worms. They each measured approximately a yard in length, and in the shape of the head and segments resembled *Dibothryocephalus latus*.



Fig. 1 (case 3).—Well defined ray fungus in the center of an abscess which has developed between the cancellous trabeculae of the vertebral body.

*Microscopic Observations.*—The spinal cord showed a localized area of organizing chronic pachymeningitis. On the dura mater were many fresh colonies of *Actinomyces*. Chronic purulent fibroid pneumonia, multiple abscesses with many colonies of *Actinomyces*, large areas of fibrosis, areas of regenerating alveoli (cells of Tripier), chronic adhesive pleuritis, old organized empyema, excessive anthracosis and bronchiectatic abscesses were found on the lungs. Extreme anthracosis, hyperplasia of the reticulo-endothelium with many phagocytes filled with hemosiderin and abscesses with colonies of *Actinomyces* were noted in the bronchial nodes. The spleen and liver showed hemosiderosis. Multiple actinomycotic abscesses with destruction of the bone (figs. 1 and 2), chronic purulent osteomyelitis with numerous colonies of *Actinomyces* and markedly hyperplastic

search for *Actinomyces* as a diagnostic fetish, and his successes with bold surgical intervention would lead one to suggest that the patient's interests are best served if a presumptive diagnosis of actinomycosis is made in cases in which the evidence is complete, except for the finding of *Actinomyces*, and radical surgical measures adopted early in the course of the disease.

#### TERMINOLOGY

Much confusion and controversy has attended the attempts to designate this disease properly. Harz, after studying the disease in cattle, gave the name "actinomycosis bovis" to the organism in 1877.<sup>35</sup> A year later, Israël<sup>3</sup> isolated a similar organism in man. At least a dozen different names have since been applied to the same disease, but, thanks to the efforts of the Committee of the Society of American Bacteriologists on Characterization and Classification of Bacterial Types, this difficulty is rapidly being overcome. In 1920,<sup>36</sup> they recommended that the generic name *Actinomycosis* be used for all of these closely related and probably identical species: *Streptothrix* Cohn, *Discomyces* Rivolta, *Nocardia* Trevisan, *Micromyces* Gruber, *Oöspora* Sanvagean and Radais, *Thermoactinomyces* Tsilinsky and *Colmistreptothrix* Pinony, with *Actinomycosis bovis* of Harz as the type species.

#### TREATMENT

The most important preliminary step to rational treatment is the early establishment of the correct diagnosis. In the thoracic and abdominal cases, with vertebral involvement, the possibility of cure is at best remote. One cannot but be encouraged, however, by the brilliant results that have followed bold attempts at the extirpation of all diseased tissue by courageous surgeons, notably Brickner, during the past decade. Brickner injects methylene blue into the sinus. Aided by the direction taken by the blue dye and the use of a probe, he extirpates all anatomically accessible diseased tissues, going well beyond the margin of disease, and treats actinomycosis much as a malignant growth. In one of his five successfully treated, consecutive cases, eight extensive operations were required before cure was obtained.

All drug therapy in actinomycosis is employed on an empiric basis. The favorite has been potassium iodide. Thomassen<sup>37</sup> first used it in 1885 in treating cattle that had buccal actinomycosis. Nocard, in 1893,

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35. Harz: *Actinomycosis bovis*, ein neuer Schimmel in dem Gewebe des Rindes, München. Jahresb. d. Muenchener Central Thierarznei Schule, 1877-1878, p. 125.

36. Winslow, Broadhurst, Buchanan, Krumwiede, Rogers and Smith: The Families and Genera of the Bacteria, J. Bact. 5:191, 1920.

37. Thomassen: L'Echo Vet., 1885.

marrow with many pigmented phagocytes containing hemosiderin were found in the vertebrae. Intestinal worms, *Dibothrycephalus latus*, were found<sup>32</sup> and many typical eggs were found in feces.

*Pathologic Diagnosis.*—The diagnosis was: chronic actinomycosis of the lungs, pleura, vertebrae (seventh cervical to ninth thoracic) and meninges; diffuse chronic fibroid pneumonia with multiple abscesses; bilateral empyema, with left-sided multiple sinus tracts opening through skin posteriorly; atrophy, fatty infiltration and fatty degenerative infiltration of heart; hydropericardium; hemosiderosis of liver, spleen, lymph nodes and bone marrow; severe anemia; *Dibothrycephalus*

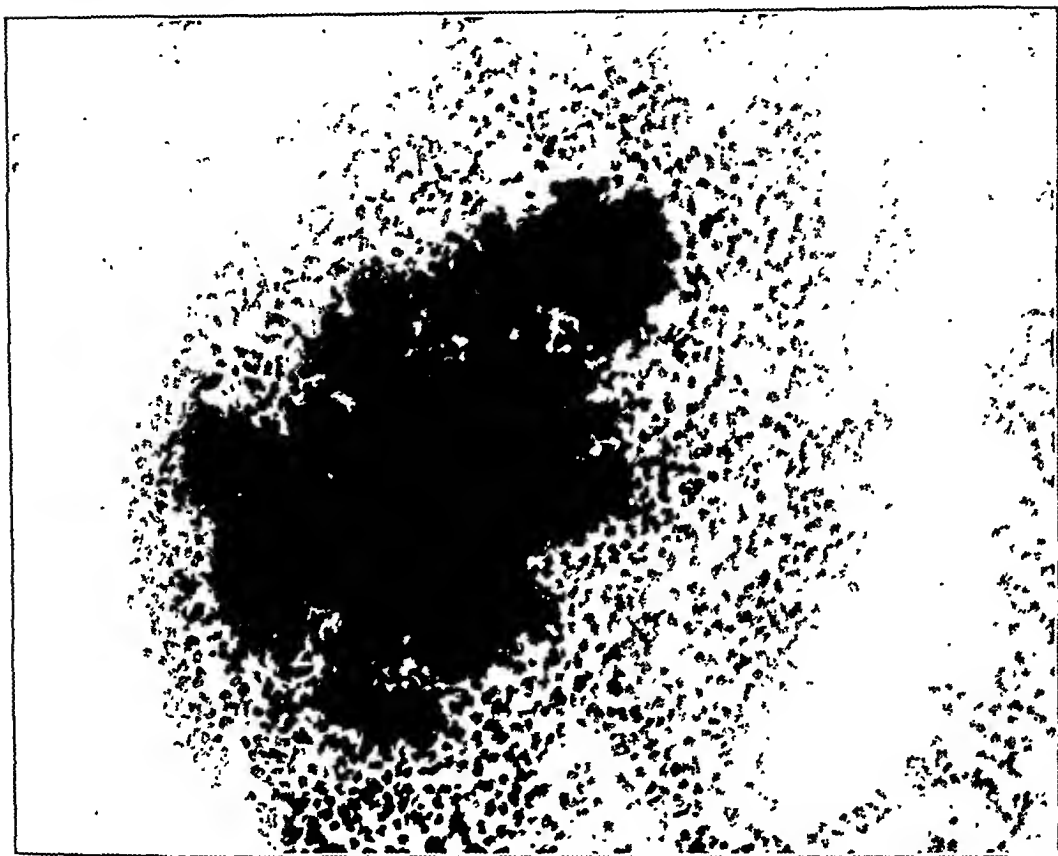


Fig. 2 (case 3).—High power photomicrograph of actinomyces in vertebral marrow space, showing densely interwoven mycelium in the center and radiating clubs at the periphery, surrounded by polymorphonuclear leukocytes.

*latus* infestation (two worms); atrophy, passive congestion and parenchymatous degeneration of all organs; moderate atherosclerosis; hypoplasia of the suprarenals; aspermatogenesis, and marasmus.

CASE 4.—*History.*—H. V., an American farmer, aged 41, admitted to the University of Michigan Hospital on April 16, 1926, complained of discharging sinuses which drained through an old appendectomy scar and about the right iliac crest. He had been in good health until six months before, when he was operated on for acute appendicitis. The appendix, he said, had perforated, and

32. The discovery of the fish-tapeworms at autopsy and the abundant evidence of blood destruction will be made the subject of a later paper.



regarded it as infallible. Most veterinarians in this country still look on it as practically a specific.<sup>38</sup> Many have ascribed cures to its use. As many others have not found it efficacious. Harbitz and Grondahl<sup>39</sup> found that the fungus grew luxuriantly in agar, under anaerobic conditions, to which from 1 to 2 per cent of potassium iodide had been added. It is still used in practically every case of actinomycosis in man, and is prescribed much as in the treatment of syphilis, beginning with small doses which are gradually increased to the point of tolerance. As much as 700 grains (45.5 Gm.) a day has been administered without discomfort, but in the case in which the massive doses were employed there was not demonstrable benefit. In addition to the oral administration of potassium iodide, intravenous injections of sodium iodide (10 per cent solution in increasing doses from 20 cc. to 100 cc. a day) is a popular treatment. Iodine has also been used in the form of solutions for irrigation of the sinuses (Lugol's solution, half strength or 2 to 4 per cent aqueous solution). Surgical solution of chlorinated soda has been used by many, with varying success. Copper sulphate irrigations in 1 to 2 per cent solutions appear to have been of some value in lesions of the mouth and neck, but have been of little use in the deep lesions of the thorax and abdomen. The roentgen ray and radium are used in many clinics, and have given favorable results in a few cases. Vaccine therapy has been employed by many,<sup>40</sup> with apparent success. The value of vaccines is difficult to measure, because they are usually employed in conjunction with surgical measures and other medicinal treatments. The problem of therapy is rendered still more difficult by the fact that there are some cases of actinomycosis which apparently regress spontaneously.

A study of these cases seems to prove that bold surgical measures give to the patient with deep-seated actinomycosis his best chance for recovery. Iodization, the roentgen ray and other therapeutic measures, should be employed only as adjuvants.

38. Salmon and Norgaard: Eighth and Ninth Annual Reports, Bur. Animal Indust., U. S. Dept. Agric., 1893, p. 109.

39. Harbitz and Grondahl: Actinomycosis in Norway, *Am. J. M. Sc.* **142**: 386, 1911.

40. Colebrook (footnote 34) Wynn: A Case of Actinomycosis (Streptotrichosis) of the Lungs and Liver Successfully Treated with a Vaccine, *Brit. M. J.* **1**:554, 1908. Dean: A Case of Actinomycosis Successfully Treated by Vaccines, *Brit. M. J.* **1**:82, 1917. Scott: Bovine Actinomycosis, Its Pathogenesis and Treatment by Vaccines, *Brit. M. J.* **2**:1163, 1922. Collie: A Case of Actinomycosis Treated by a Vaccine, *Brit. M. J.* **1**:991, 1913. Malcolm: Vaccine in Mediastinal Actinomycosis, *Brit. M. J.* **2**:488, 1916. Whittier: Case of Actinomycosis Improving Under Vaccine Treatment, *J. A. M. A.* **52**:1453 (May 1) 1909. Harbitz and Grondahl (footnote 39), Kinnicut and Mixter: Actinomycosis Treated with Vaccines, *Boston M. & Surg. J.* **167**:90, 1912. Friedmann: Heilimpfung der Aktinomykose, *München. med. Wchnschr.* **70**:176, 1923.

following the operation the wound drained for about a month. About two months later, he returned to the hospital for treatment of a left inguinal hernia. After four weeks in the hospital, he returned home but did not gain in strength or weight. Shortly after this a sinus appeared at the site of the appendectomy scar, and discharged a thin, light yellow pus. About four weeks later, a second sinus appeared just above the right iliac crest. He then became unable to extend the right thigh, and a position of marked flexion gradually developed. He did not have any symptoms directly referable to the spine. He lost about 50 pounds (22.7 Kg.) in weight during his illness. His family and personal history contained nothing relative to his condition.

*Physical Examination.*—The patient was greatly emaciated. He was anxious and pale, and appeared acutely ill. There was some dulness to percussion posteriorly from the angle of the scapula to the apex of the right lung. Some fine râles were heard over this area as well. There was a reddened right rectus surgical scar with some discharge of thick, creamy pus. A discharging sinus was present in the right lumbar region just above the iliac crest. Palpation of the right lower quadrant and lumbar region revealed indefinite evidence of abscess formation. There was marked tenderness over the lumbar vertebrae, with muscle spasm. There was psoas spasm and flexion of the right thigh. The hip joint appeared to be negative.

*Special Examinations.*—Urinalyses were negative. The white blood count was 12,100, with a normal differential count; the hemoglobin content was 38 per cent. Microscopic examination of the pus from the sinuses showed masses of leukocytes, mostly mononuclears. Repeated examinations failed to show actinomycotic colonies. Stereoscopic films of the spine and abdomen following injection of barium into the sinus tracts showed an extensive involvement of the tissues of the back. The process was not definitely connected with the bodies of the vertebrae, as the sinus tract lay more posteriorly, but seemed to involve the transverse process of the third lumbar vertebra.

*Course of Disease.*—The patient's temperature varied from 98 to 101 F. His pulse rate remained persistently elevated, between 90 and 110. After eleven days he became much weaker, passed into a state of delirium and died.

Clinically, this was considered a case of Pott's disease.

*Autopsy.*—(Prosectors, Drs. McIntosh and Simpson.) The body was that of a white man, and showed marked emaciation. The bony frame was large, and the muscles were extremely atrophic. An old appendectomy scar contained the openings of two fistulous tracts. The lower communicated with a discharging sinus that was situated in the scar of a herniotomy on the right side, while the upper communicated with a discharging sinus above the right iliac crest. A probe was readily passed by either opening in the appendiceal scar through soft necrotic tissue into the abdominal cavity. When the sinus in the herniotomy scar was probed, it in turn led into the scrotum, where an opening was found on its right anterior surface, which, on pressure, exuded thick creamy pus. About 5 cm. above the crest of the ilium in the scapular line there was a sinus opening, which when probed led deeply into the muscles of the loin.

On opening the abdomen a generalized purulent peritonitis was found, and the right flank and pelvis contained 300 cc. of thick, yellowish, creamy pus. About the cecum there were firm fibrous and fibrinous adhesions, and the inflammatory process extended up behind the liver, where there were small abscess cavities and much granulation tissue; in this region the right lobe of the liver was involved.

The liver, on section, showed multiple large abscesses, each of which in turn was composed of smaller abscess units separated by firm connective tissue septums,

## SUMMARY

1. Actinomycosis is a much more common disease in the United States than a study of the literature would lead one to believe.

2. Four cases of actinomycosis of the vertebrae have been encountered in the Pathological Laboratory of the University of Michigan. All came to autopsy with a clinical diagnosis of tuberculosis of the spine. Two of these cases occurred within the past year.

3. Actinomycosis of the bone is not so rare as is generally believed.

4. In two of our cases, the primary infection was in the lungs; in the other two, the primary focus was apparently in the appendiceal region. The spread of the actinomycotic process to the vertebrae was due to direct extension by means of dissecting sinus tracts and abscesses.

5. In actinomycosis of the spine, the characteristic lesion is cortical erosion of the vertebrae with vertebral phlegmon, while in tuberculosis the disease causes progressive destruction of the bodies, with collapse and angular deformity. Central destruction of the body of the vertebra, with ultimate collapse and deformity are not found in vertebral actinomycosis. The roentgenogram should easily distinguish the two conditions.

6. The many other causes of psoas abscesses should be considered before a diagnosis of tuberculosis is made. The development of multiple sinus tracts, with brawny induration of the surrounding tissues, and the persistent absence of the tubercle bacillus should direct one's thoughts to a consideration of actinomycosis.

7. The pathognomonic "ray fungi" should be looked for by the surgeon who first drains an actinomycotic abscess. Subsequent secondary pyogenic infection renders the search more difficult.

8. Curettement of the granulation tissue wall of a sinus tract, with histopathologic examination of the fragments, will often establish the diagnosis after frequent examinations of the pus for actinomycetes have proved fruitless. The finding of lipoid cells in the granulation tissue lends support to the probability that the disease is actinomycosis.

9. Radical surgical excision of all involved tissue offers the best hope of cure.

# SIMPSON-McINTOSH—ACTINOMYCOSIS OF PERITONEAL TUBES

giving the large abscesses a loculated appearance. The honeycomb like structure of the abscesses at once suggested actinomycosis. Definite actinomycotic granules were not visible to the naked eye.

About the right kidney there was the same involvement as elsewhere. There were small abscess pockets and large areas of fibrosis. The kidneys themselves were not involved, but showed grossly the uniformly granular subcapsular surfaces of chronic glomerulotubular nephritis.

The right psoas muscle was practically entirely replaced by abscess, granulation tissue and numerous sinus tracts. These extended deep into the muscles of the loin, and when probed were found to lead to the transverse processes of the

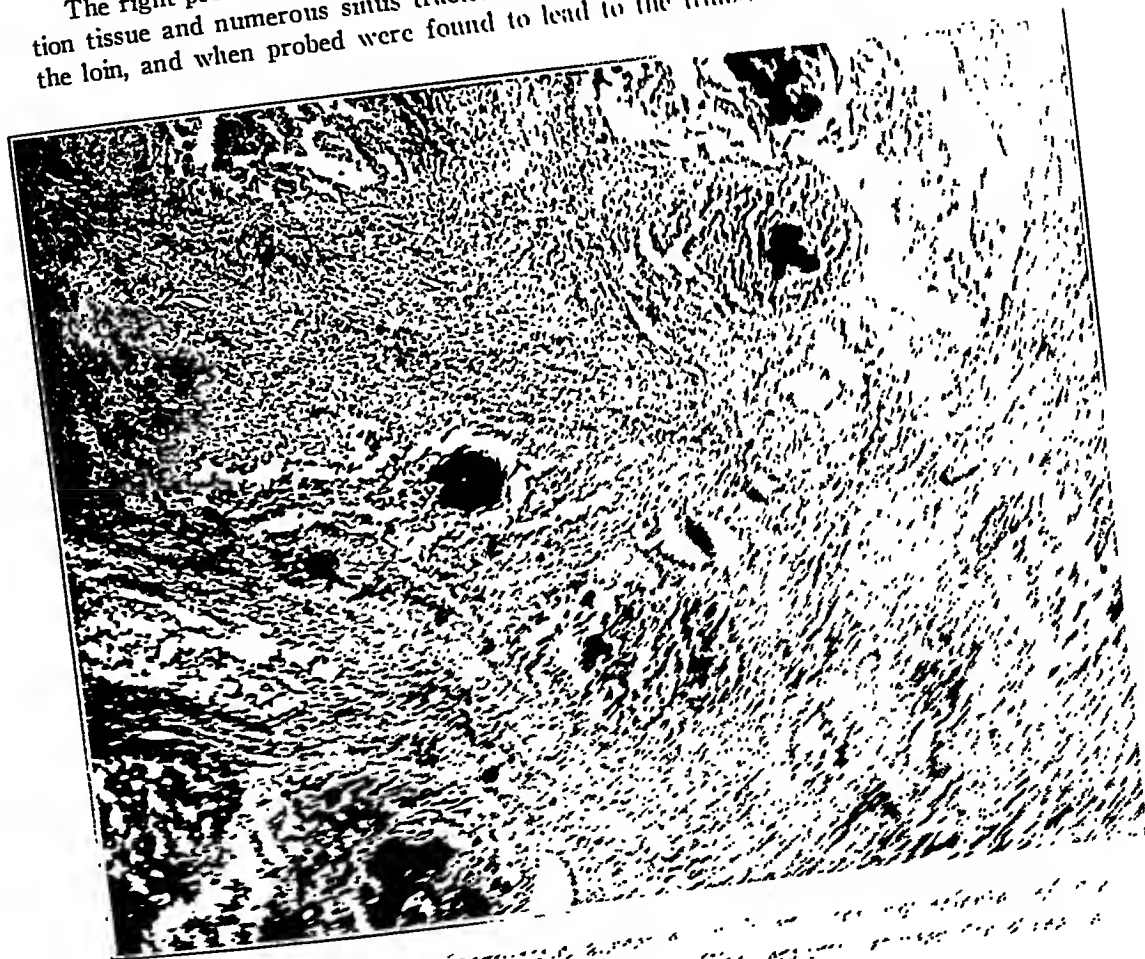


Fig. 1. — Actinomycosis of the right psoas muscle. The abscesses are numerous and of varying size. The granules are visible in the center of some of them. The abscesses are loculated and the tissue is heavily infiltrated with granules.

The abscesses were found to be numerous and of varying size. The granules were visible in the center of some of them. The abscesses are loculated and the tissue is heavily infiltrated with granules.

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# SARCOMA COMPLICATING PAGET'S DISEASE OF THE BONE

REPORT OF NINE CASES, FIVE WITH PATHOLOGIC VERIFICATION \*

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In the last of Paget's three classic papers,<sup>1</sup> he expressed the conviction that there is an intimate relationship between the disease which has come to bear his name and the formation of malignant tumors. This belief was based on the fact that among his twenty-three personally observed patients with the disorder, five of the eight who were traced to the end died from malignant disease of some kind.

The tumor of only one of these patients was definitely an osteosarcoma, although that of another patient was probably of this nature. Paget says, concerning the first:

The upper third of the radius was involved in a large ovoid mass of pale grey and white soft cancerous substance, similar to that of the nodules in the pleurae and mediastinum, but with growths of bone extending into it. Some nodules of similar cancerous substance were imbedded in the bones of the vault of the skull.

The second case was not unlike the first; a fracture occurred at the site of a growth in the upper portion of the right humerus, necessitating an amputation at the shoulder joint. The lesion was described as "a well marked and very vascular medullary cancer investing and infiltrating the upper part of the humerus."

Although isolated examples of osteosarcoma and other tumors occurring in the disease were thenceforward reported, an attempt to assemble all of the cases subsequent to Paget's papers was not made until 1901, when Packard, Steele and Kirkbride<sup>2</sup> collected sixty-six authentic instances of the disorder, five of which were complicated by osteosarcoma (7.5 per cent), three by carcinoma in some portion of the body (4.5 per cent) and two by nonmalignant tumors. "When we bear in mind," say these authors, "that osteitis deformans is especially prone to affect those beyond middle age, it is not surprising that about 4.5 per cent of the cases had cancer, although the high percentage of 7.5 per cent of sarcoma must have some significance."

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\* From the Surgical Clinic of Dr. Harvey Cushing.

1. Paget, Sir James: Remarks on Osteitis Deformans, *Illus. M. News* 2:181, 1889.

2. Packard, F. A.; Steele, J. D., and Kirkbride, T. S.: Osteitis Deformans, *Am. J. M. Sc.* 122:552, 1901.

*Microscopic Observations.*—The spinal cord showed only congestion and edema. Well marked subendocardial fatty degenerative infiltration of the heart extended deeply into the wall, but there were small areas of fibrosis which did not show active inflammatory infiltrations. There was moderate atherosclerosis of the coronary arteries. There was localized chronic perisplenitis and chronic passive congestion of the spleen without amyloid. Chronic productive perenteritis, with more recent purulent peritonitis, was present in the small and large intestines (fig. 3).

Large abscess areas on the liver were made up of multiple small abscesses separated by connective tissue septums. In the center of nearly every one of the

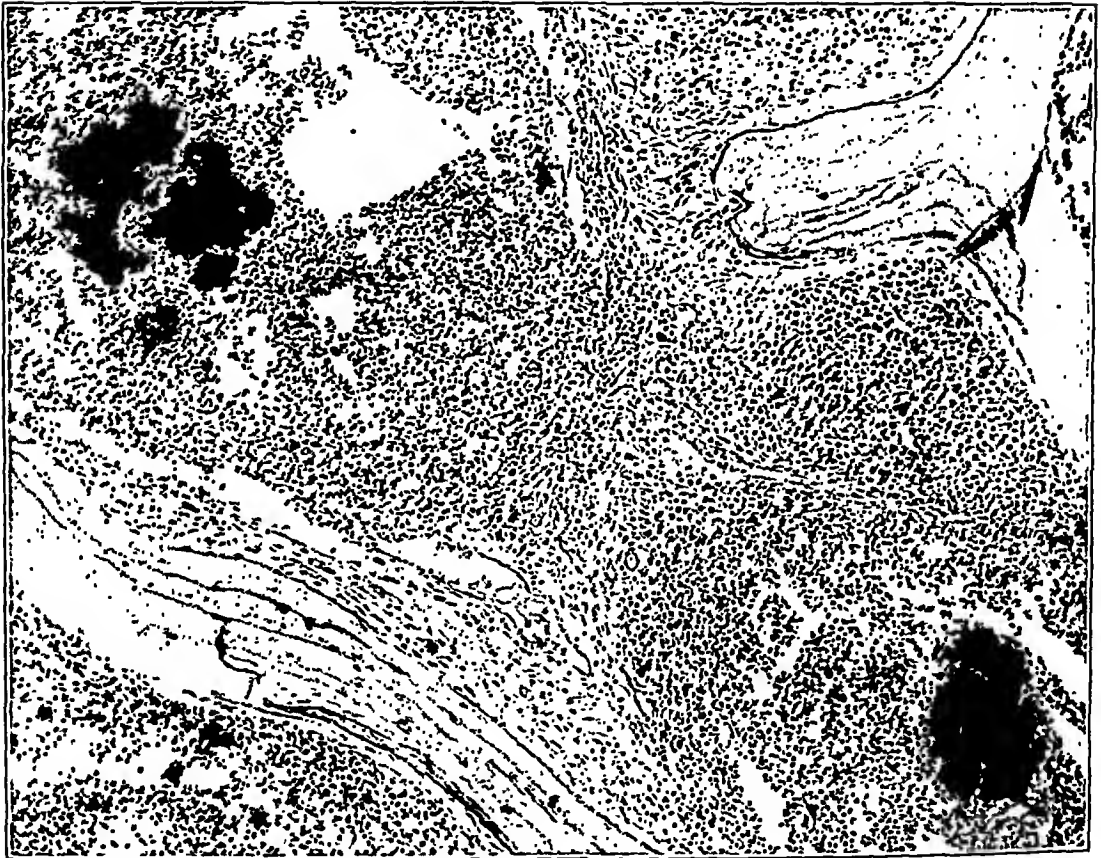


Fig. 4 (case 4).—Multiple actinomycotic abscesses, with characteristic lipid granulation tissue, in lumbar vertebra. Ray fungi show distinct peripheral clubs.

smaller abscesses was an actinomycotic colony, with well defined central mycelium and distinct peripheral radiating clubs. The septums and peripheral zone of the abscesses were made up of old hyalinized repair tissue, while the small abscess units were lined by a younger fibroblastic and angioblastic granulation tissue, rich in lipid cells. The liver cells at the periphery showed pressure atrophy, with regenerative proliferation of the bile ducts. Fatty infiltration was most marked at the periphery of the lobules, and there was slight diffuse fatty degenerative infiltration (fig. 4).

The marrow spaces of the lumbar vertebrae were filled with pus cells and lipid granulation tissue containing scattered ray fungi. There was considerable destruction of the bone trabeculae. The right psoas muscle showed chronic

Two papers, one by Gruner, Scrimger and Foster<sup>3</sup> in 1912, and another by DaCosta, Funk, Bergeim and Hawk<sup>4</sup> three years later, have dealt specifically with malignant complications in Paget's disease, each reporting about 9 per cent of tumors of all varieties. In 1917, Heazlit<sup>5</sup> described a case in which there were multiple sarcomas, and Camp<sup>6</sup> has more recently recorded two cases of sarcoma in which the diagnosis of coincidental Paget's disease was established on roentgen-ray evidence. In a review of his personal records, among sixty-five patients with instances of the disorder, Locke<sup>7</sup> found four with osteosarcoma or fibrosarcoma (6.2 per cent).

#### REPORT OF CASES

My interest in the subject was initiated by the unfortunate individual whose clinical history follows:

*CASE 1.—Enlargement of the calvarium over a period of ten years. Recent growth of large sarcoma of skull. Partial removal of tumor. Roentgen-ray treatment. Necropsy.*

C. B., a nurse, aged 66, unmarried, was admitted on Nov. 20, 1923, with an obvious enlargement of the skull and an immense soft growth beneath the scalp in the left parietal region (fig. 1A). In the center of this mass was a herniated nubbins where an incision had been made, probably with the expectation of draining an abscess. Other physical changes were not apparent except that she looked a little pale and showed evidence of moderate loss in weight.

In the absence of any noticeable abnormalities in the skeleton with the exception of the large skull, suspicion of Paget's disease was not aroused until the cranial roentgenograms disclosed an advanced state of the disorder in addition to a large irregular area of bone destruction in the region of the tumor (fig. 2). Subsequent roentgenograms of the remainder of the skeleton disclosed unmistakable alterations in the upper ends of the femora, in the pelvis and in the lumbar spine.

In an effort to prevent the occurrence of a foul fungating mass, Dr. Cushing reflected the tense scalp from over the tumor and roughly extirpated the major portion of it. The small fungus was then excised from the scalp, the galea being closed from within. A clean closure of the scalp was thus effected (fig. 1B).

As anticipated, the growth rapidly recurred, and the patient died three months later. Permission was secured for an unrestricted autopsy with removal of the

3. Gruner, O. C.; Scrimger, F. A. C., and Foster, L. S.: A Clinical and Histologic Study of a Case of Paget's Disease of the Bones with Multiple Sarcoma Formation, *Arch. Int. Med.* 9:641 (June) 1912.

4. DaCosta, J. C.; Funk, E. H.; Bergeim, O., and Hawk, P. B.: Osteitis Deformans: A Report of Five Cases, with Complete Metabolism Studies in Two Instances and a Review of the Literature, *Pubs. Jefferson Med. Coll. and Hosp.* 6:1, 1915.

5. Heazlit, L.: Sarcoma Complicating Paget's Disease of Bone: Report of Case, *N. Y. State J. Med.* 17:330, 1917.

6. Camp, J. D.: Sarcoma Complicating Osteitis Deformans: A Report of Two Cases, *Radiology* 5:495-499, 1925.

7. Locke, E. R.: Personal communication, July 9, 1925.

the roentgenograms leave no reasonable doubt that the condition was a sarcoma, probably of the endothelioma type.

CASE 33.—*Fibroperiosteal sarcoma of femur.* B. M., a woman, aged 33, first felt pain in the right knee in March, 1918; six months later a swelling appeared and slowly increased in size. An exploratory operation was performed by



Fig. 58 (case 133 in table 7).—Periosteal sarcoma of femur.

Dr. George Wooley at Peekskill Hospital, Jan. 25, 1919. The microscopic diagnosis was fibrosarcoma. The patient was admitted to Memorial Hospital, in the service of Dr. H. H. Janeway, March 13.

Physical examination at this time showed a swelling, the size of a small orange, in the lower extremity of the right femur. The clinical diagnosis was sarcoma of the femur. March 13, the patient received a radium treatment in the form of a pack, 14,804 millicurie hours at 6 cm. distance; in addition, she received



five roentgen-ray treatments from May 23 to September 22. The disease was under almost complete control for a period of more than three years. At the end of this time, there was evidence of recrudescence accompanied by bone destruction and a pathologic fracture occurred. The leg became useless and was amputated by Dr. Woolsey, March 27, 1924. The microscopic diagnosis of Ewing was long spindle cell fibrosarcoma with occasional points of hyaline osteoid tissue. She was reported well in August, 1926, two and one-half years after amputation.

CASE 34.—*Tumor of the left tibia, endothelioma (?)*; roentgen-ray radiation; recovery; well two and one-half years later.

S. L., a woman, aged 19, fell downstairs in February, 1922, striking the left leg just below the knee; two months later she felt a sharp pain radiating from the knee to the thigh and hip. She was admitted to the Hospital for Ruptured and Crippled in the early part of September, and was treated with local applications without relief. The left leg became greatly swollen, and walking became very difficult; her temperature rose to 101-102. Dr. Percy Roberts made a diagnosis of osteomyelitis and advised operation. This diagnosis was confirmed by roentgen-ray findings. The patient was referred to the outpatient department of the Memorial Hospital, September 26. Physical examination on admission showed a diffuse swelling over the anterior aspect of the left tibia just below the head. The circumference of the left calf at that point measured 11 inches (27.9 cm.); the opposite calf measured 10¾ inches (27.2 cm.). The swelling covered an area from about 5 to 6 cm. wide; it was slightly elevated and somewhat tender on pressure.

Roentgen-ray examination by Dr. R. E. Herendeen, September 29, stated: "The plate of the tibia reveals evidence of changes in the upper third; it has some of the features seen in an endothelioma. It lacks the appearance usually noted in periosteal growths or giant cell tumors. The diagnosis is endothelioma. The plate of the lungs does not reveal definite evidence of metastases."

The patient received six roentgen-ray treatments from September 26 to December 29. Roentgen-ray examination, Nov. 7, 1923, showed marked improvement in the condition of the tibia, with no evidence of a recurrence; the patient's general health was excellent.

In the absence of a microscopic examination in this case and the fact that there were several features pointing to osteomyelitis, it cannot be regarded definitely as a malignant tumor. Our diagnosis at the time treatment was begun was osteitis.

CASE 35.—*Osteogenic sarcoma of femur*. I. L., a man, aged 20, was admitted to the Hospital for Ruptured and Crippled, March 13, 1925. In March, 1921, four years before, the patient's left leg was caught in the door of a subway train and was severely squeezed. Three days later he felt some pain, which became more severe and localized over the greater trochanter; the pain was of an intermittent nature, and kept the patient in bed only a few days at a time; however, the attacks became more frequent. He was admitted to the Jewish Hospital of Brooklyn, July 25, 1923, where an operation (osteotomy and curetting of bone) was performed, August 7. The microscopic diagnosis was osteomyelitis. Roentgenograms taken at this time showed nothing at all suggestive of sarcoma, only a marked thickening of the femur with sclerosing of the bone, typical of a chronic sclerosing osteitis.

A roentgenogram taken at the time of the patient's admission to the Hospital for Ruptured and Crippled showed that certain changes had taken place since the

system. This examination substantiated the clinical impression of osseous deformations of the skull, spine, pelvis and femora and of osteosarcoma of the skull (fig. 3), while microscopic sections from the skull showed the bone of Paget's disease invaded by the sarcoma (fig. 4). There were metastases in the cervical lymph nodes.



Fig. 1 (case 1).—A, large head with fungating tumor just before operation. B, postoperative condition of the scalp.



Fig. 2 (case 1).—Ossous tumor appearance of Paget's disease with irregular destruction due to the sarcoma.

With the memory of this patient fresh in mind and while the relationship between osseous deformations and malignant bone tumors in the dog was under discussion, another example of a similar process occurring in the feline appeared in the clinic. The history follows:



Fig. 17 (case 5).—The ilium largely destroyed by sarcoma.



Fig. 18 (case 5).—Metastasis of the sarcoma in bone of osteitis deformans. Calvarium. Hematoxylin and eosin stain;  $\times 80$ .



Fig. 3 (case 1).—Destruction of the thickened bone by the sarcoma.



Fig. 4 (case 1).—The bone of Paget's disease infiltrated by sarcoma (left lower corner). Hematoxylin and eosin stain;  $\times 80$ .

Eight years later, in 1922, he again appeared because of a firm enlargement at the summit of the same shoulder. This had grown to the size of an orange in six weeks and was very painful. Roentgen-ray examination disclosed, in addition to the osteitis deformans, a destructive process with bone production in the region of the outer end of the clavicle and the upper portion of the scapula (fig. 19). Photomicrographs of sections obtained from the amputated upper extremity showed the characteristic lesion of osteitis deformans and the adjacent osteosarcoma (figs. 20 and 21).

Shortly after operation, a hard nodule appeared in the frontal bone and grew progressively larger. He became emaciated, had repeated hemoptysis and died one month later. Autopsy was not performed.

Investigation of the records at the Registry of Bone Sarcoma<sup>9</sup> brought to light, among their 670 cases of all types, benign, malignant and inflammatory, three more instances of malignancy superimposed



Fig. 19 (case 6).—The sarcoma has arisen in the clavicle affected by osteitis deformans. Note the cotton-tuft appearance of the head of the humerus as well.

on Paget's disease. The first patient, as in case 1, had a primary growth in the thickened cranial vault.

*CASE 7.—Typical photographic appearance and roentgen-ray picture of Paget's disease. Sarcoma of skull (biopsy). Death with hemiplegia. Autopsy was not performed.*

S. C., a farmer, aged 69, reported to his physician because of a hard swelling in the right frontal bone which had been present for eight months and had rapidly grown larger over a period of four weeks. A photograph (fig. 22), a roentgenogram of the skull and a section of the tumor growth make a diagnosis of Paget's disease, with osteosarcoma of the skull, probable.

The enlargement of the calvarium, the dilated and tortuous temporal artery and the projection of the head are significant, while the roentgenogram shows

9. Registry of Bone Sarcoma of the American College of Surgeons, Dr. D. B. Phemister, Registrar, Chicago.

CASE 2.—Osteosarcoma of ilium. Paget's disease of ilium, skull and other bones by roentgen ray. Palliative radiographic treatments. Necropsy not performed.

M. W., an Irish-American boilermaker, aged 60, entered the hospital on Feb. 5, 1924, for roentgen-ray treatment of a huge, firm, fixed swelling in the right gluteal region, apparently originating from the ilium (fig. 5). The tumor



Fig. 5 (case 2).—Sarcoma arising in the ilium.

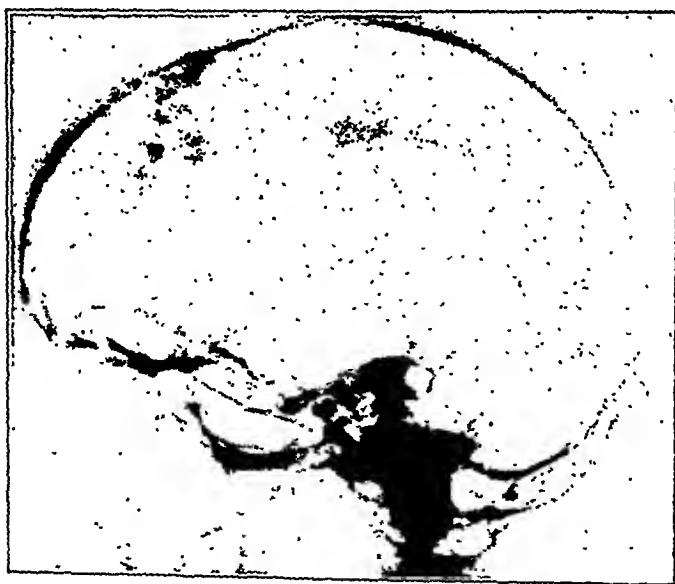


Fig. 6 (case 2).—Early Paget's disease in the skull.

had grown slowly over a period of eight months, causing pain, paralyses and paresthesias consistent with pressure on the lower lumbar and sacral nerves of the right side. By rectal examination a large mass could be felt filling the concavity of the sacrum on the right side.

Roentgenograms were made of the entire skeleton. These showed, in addition to the spicule formation of an osteosarcoma in the ilium (fig. 7), the alternate

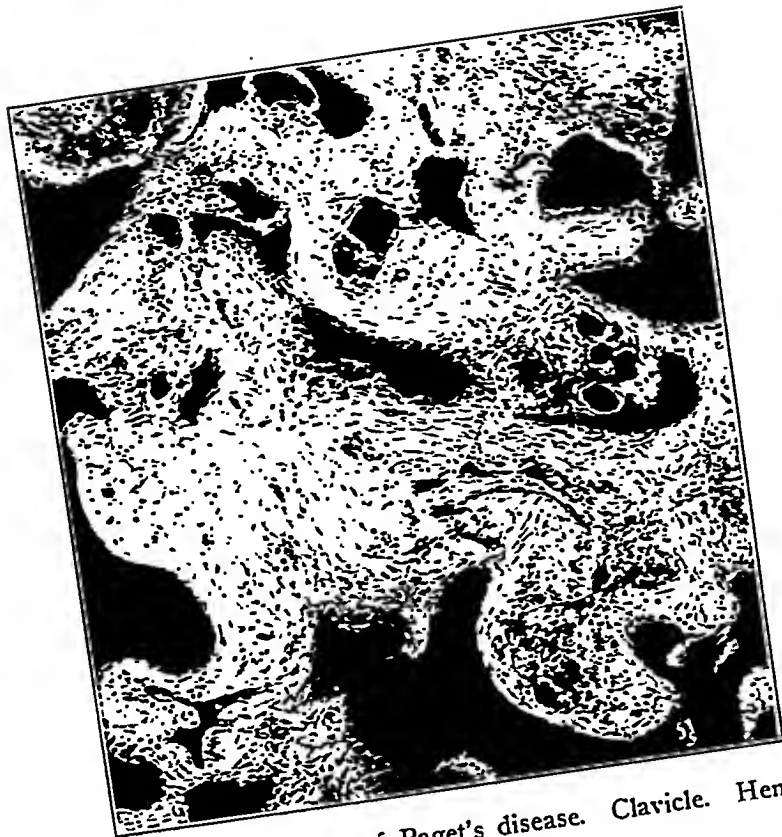


Fig. 20 (case 6).—The bone of Paget's disease. Clavicle. Hematoxylin and eosin stain;  $\times 80$ .

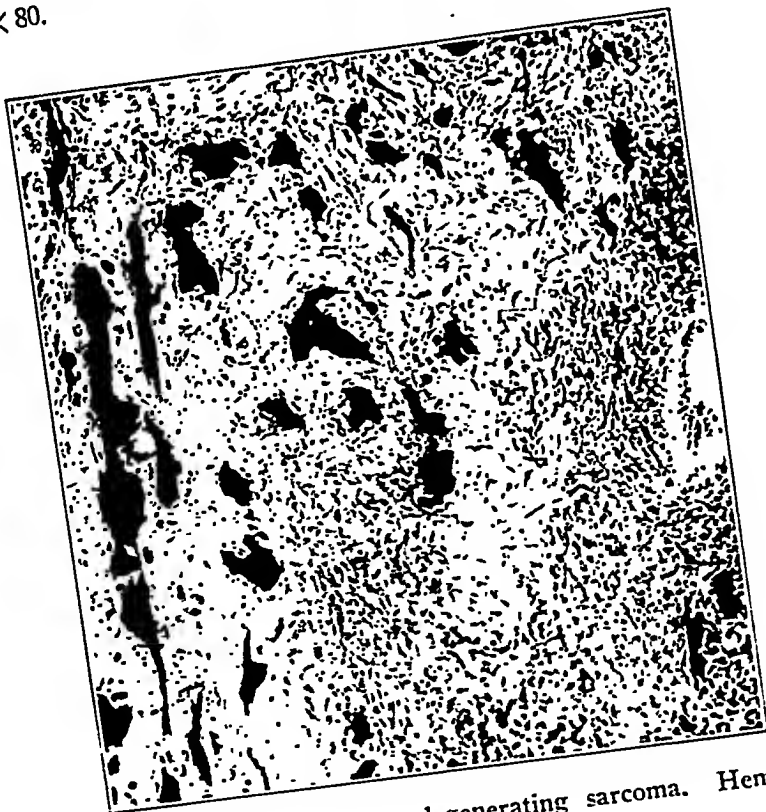


Fig. 21 (case 6).—The adjacent degenerating sarcoma. Hematoxylin and eosin stain;  $\times 80$ .

areas of increased and decreased density characteristic of osteitis deformans in the bones of the pelvis, the upper ends of the femora, the lumbar and lower dorsal spine, the upper ends of the humeri, and, most interesting of all, a very early process in the skull (fig. 6).

Eight deep roentgen-ray treatments were given, which decreased the pain and apparently checked the advance of the growth. Evidences of pulmonary involvement with a cough and hemorrhages soon appeared, and the man died at his home one year after the onset of his illness. Necropsy was not performed.

A third example of sarcoma involving the humerus in a case of Paget's disease was subsequently found in the Brigham hospital records.



Fig. 7 (case 2).—Osteitis in the pelvic bones and femur. Spicule formation by the sarcoma.

A complete preoperative report of this case has already appeared in Locke's paper.<sup>8</sup>

*CASE 3.—Paget's disease for eleven years. Recent growth of a painful sarcoma at the right elbow. Amputation at the shoulder girdle with relief. End-result not known.*

M. S., an English violinist, aged 63, known to have had osteitis deformans for eleven years, became afflicted with a painful swelling of the right elbow (fig. 8). Roentgenograms showed widespread Paget's disease, including the skull (fig. 9)

8. Locke, E. A.: Osteitis Deformans with Sarcoma of the Humerus, *M. Clin. N. Amer.* 1:947, 1917



the variations in density with the thickening of the skull which is characteristic of the disease. The area of local bone destruction is similar to that in the roentgenogram of the skull in case 1 (fig. 2).

When a biopsy had been made, the patient was sent home. He became hemiplegic on the right side, and died one year after the appearance of the cranial tumor. From the section submitted for microscopic study, the consensus of opinion favors the diagnosis of fibrosarcoma.

Detection of the osteitis in a second case from the Registry was due to thorough roentgen-ray study.

*CASE 8.—Sarcoma of right femur. Osteitis deformans in many bones by roentgen ray. Amputation at the hip. Death with pulmonary symptoms two months later. Autopsy was not performed.*

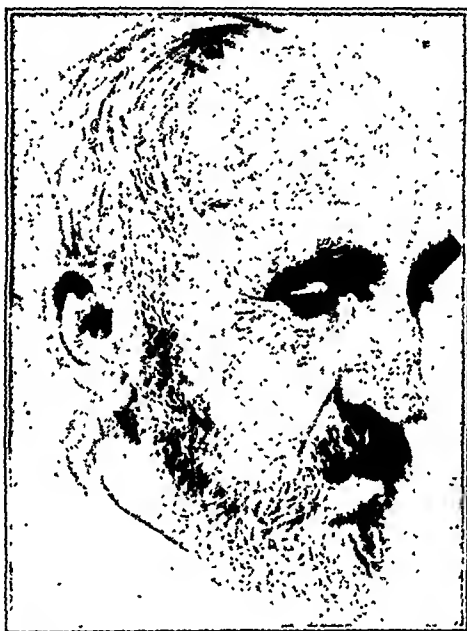


Fig. 22 (case 7).—Paget's disease with sarcoma of the frontal bone.

C. H., aged 56, a banker previously in good health, "sprained" his right knee while descending a stair. Pain and swelling resulted and persisted. In four weeks a more severe distress, localized in the lower end of the femur, and accompanied by an enlargement over the outer side of the thigh near the knee, caused him to seek advice. Roentgenograms showed the usual changes of Paget's disease in the upper ends of both tibiae and in the femur, together with slight thickening in the bones of the cranial vault, while the right femur was partially destroyed, evidently by the tumor.

Amputation at the hip joint was performed. Dyspnea and a cough developed, and the patient died two months later. The growth proved to be an osteosarcoma of a malignant type. (No sections of bone remote from the tumor were submitted, and none of the roentgenograms or sections of the neoplasm are suitable for reproduction.)

A third case from the Registry was extremely malignant, although at first it was thought to be of the benign giant cell tumor type.



Fig. 8 (case 3).—Sarcoma at the right elbow. Note the bowed legs.



Fig. 9 (case 3).—Thickened skull of Paget's disease.

CASE 9.—*Advancing osteitis deformans for fifteen years. Rapidly growing sarcoma of left humerus. Local curettage without relief. Intensive radiotherapy. Death with pulmonary metastases. Necropsy was not performed.*

J. J. C., a physician, aged 45, for fifteen years had noted the gradual enlargement and bowing of the bones of the lower extremities when he became troubled by a pain in the left shoulder accompanied by the rapid enlargement of a swelling in this region. After a month he was in acute distress. Roentgenograms showed a destructive process in the upper third of the left humerus. The mass was opened and locally curetted. One month later, following recurrence of the pain and swelling, a second curettage was done. A persistent cough developed, and

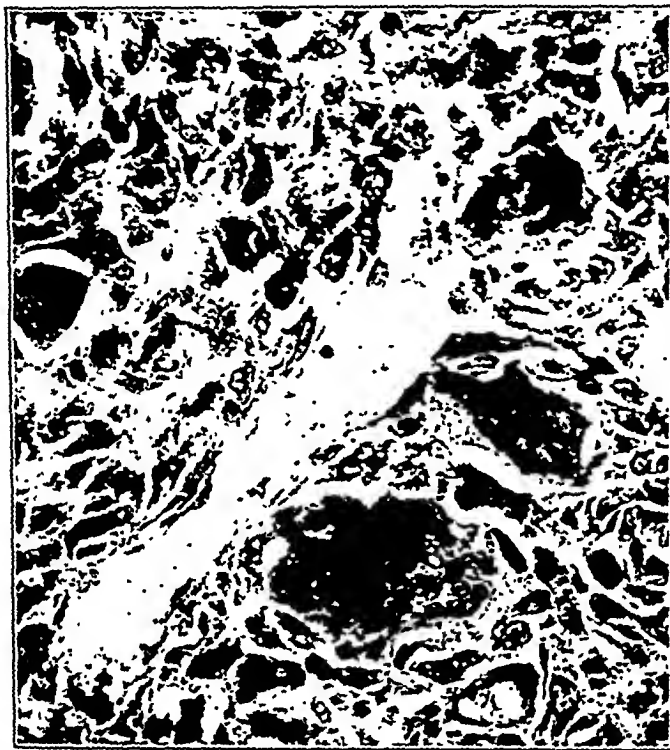


Fig. 23 (case 9.)—Rapidly growing osteosarcoma of humerus containing many foreign body and true tumor giant cells. Van Gieson's stain (?);  $\times 300$ .

roentgenograms of the chest showed metastases. In spite of intensive radiotherapy, he failed rapidly and died five months after the appearance of the mass.

Together with the destructive process due to the tumor, roentgenograms of the left humerus and right tibia showed an increase in size of the bones with the coarse, parallel trabeculations and the alternating areas of increased and decreased density of Paget's disease. (The roentgenograms are not suitable for reproduction.) Microscopic study of the tissues removed at operation showed a malignant osteogenic sarcoma containing many foreign body and true tumor giant cells (fig. 23).

#### INCIDENCE

There was approximately one case of osteitis deformans among every 15,000 patients admitted to the Boston hospitals, corresponding closely

and the bones of the extremity involved (fig. 10). The lower third of the humerus was largely destroyed by the sarcoma. An amputation at the shoulder girdle was carried out by Dr. John Homans with complete relief from pain, and the patient was discharged three weeks later, greatly improved.

The tumor probably arose from the periosteum of the humerus, destroying a portion of the bone, obliterating the joint cavity and invading the soft tissues of the forearm. Sections from the humerus showed the typical lesion of Paget's disease (fig. 11) while the growth itself was a rather slow growing fibrosarcoma (fig. 12).

In order to satisfy my curiosity as to whether other large hospitals had received similar cases, permission was given by the officials of the Boston City Hospital, the Massachusetts General Hospital, and the Huntington Memorial Hospital to examine their records and utilize them for my purposes. Three additional examples of osteosarcoma compli-

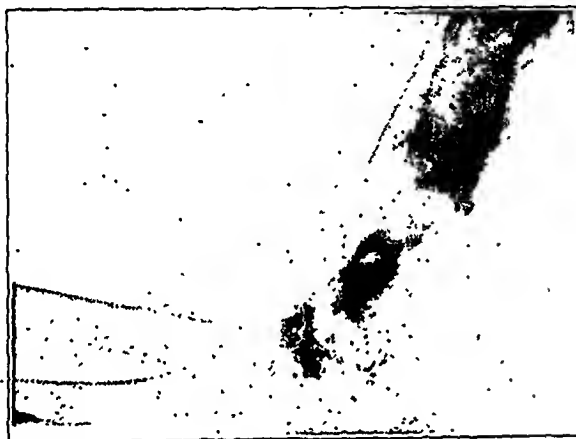


Fig. 10 (case 3).—Destruction of the humerus by the sarcoma. Humerus, ulna and radius affected by the osteitis of Paget.

cating osteitis deformans, all verified by pathologic examination, have thus been supplied. In the following case the lesion involved the head of the humerus.

*CASE 4.—Progressive deforming osteitis for fifteen years. Rapidly growing osteosarcoma of humerus. Roentgen-ray treatment without apparent benefit. Pneumonia and death. Autopsy.*

H. F., a German gardener, aged 64, married, had been admitted to the Peter Bent Brigham Hospital in 1919 because he complained of pains in the legs. Roentgen-ray study confirmed a diagnosis of osteitis deformans made on the basis of an enlarged calvarium, bowing of the back, bowing of the lower legs and a great decrease in height. The condition had been progressive over a period of from twelve to fifteen years.

Five years later, in 1924, the patient entered the Boston City Hospital because of a rapidly enlarging painful swelling of the right shoulder which had been noticed for only three weeks (fig. 13). The skin over the mass was of a purplish hue with dilated veins coursing beneath it, while the tumor itself was firmly fixed

to the reports of one in 10,000 at the Johns Hopkins Hospital,<sup>10</sup> one in 13,000 at the Jefferson Hospital,<sup>4</sup> and one in 16,000 at the Mayo Clinic.<sup>11</sup> Osteitis deformans is probably not so rare as the figures indicate. Patients with uncomplicated Paget's disease do not often find their way into our hospitals; if they should do so because of some complicating disorder, the osteitis deformans may not be indexed; and unquestionably many early examples of the malady with monosteitic manifestations have been in the past and may still be frequently overlooked. At the Peter Bent Brigham Hospital, this being the youngest of the institutions whose figures are quoted, fifteen cases have been disclosed among 45,000 persons admitted or one in 3,000, possibly because in recent years a far larger percentage of patients (80 per cent of all admissions) have had roentgenograms taken.

Sarcoma occurred as a complication in seven of the sixty-four patients with osteitis deformans recorded in the three major Boston hospitals (roughly 11 per cent). It may be assumed that lesser degrees of osteitis deformans in patients with frank sarcoma were occasionally overlooked. (The recognition of these cases would add to the recorded number of instances of Paget's disease complicated by sarcoma, but might not increase the percentage of the complication because of the relatively large number of uncomplicated cases of osteitis deformans which would also be found.)

#### DIFFERENTIAL DIAGNOSIS

Paget's disease with complicating sarcoma must be distinguished from:

1. Bone tumors with metastases: osteosarcoma (including malignant giant cell tumor), endothelioma of bone (Ewing's tumor), and multiple myeloma.
2. Metastatic carcinoma of unknown source.
3. Paget's disease with other types of tumor, including meningioma.
4. Paget's disease with syphiloma or other chronic infectious process.

When the history of osteitis deformans dates from several years before the onset of the acute symptoms of malignancy, its presence is, of course, unmistakable, but often the diagnosis can be made only by painstaking clinical and comprehensive roentgenologic examinations. In either case the local alteration at the site of the tumor will appear in the roentgenograms in addition to the more or less generalized process.

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10. Hurwitz, S. H.: Osteitis Deformans, Paget's Disease: A Report of Six Cases Occurring in the Johns Hopkins Hospital and Dispensary, *Bull. Johns Hopkins Hosp.* **24**:263, 1913.

11. Carman, R. D., and Carrick, W. M.: The Roentgenologic Aspects of Osteitis Deformans, Paget's Disease, with Reports of Fifteen Cases, *J. Radiol.* **2**:7 (April) 1921.



Fig. 11 (case 3).—The bone of Paget's disease (more vascular in this case than is usual). Hematoxylin and eosin stain;  $\times 80$ .

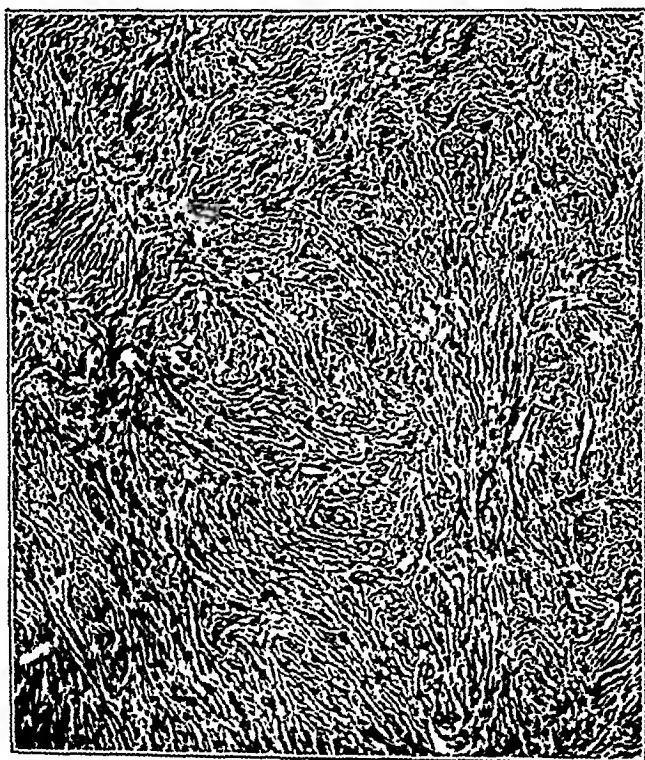


Fig. 12 (case 3).—The sarcoma. Hematoxylin and eosin stain;  $\times 80$ .

There is usually, but not always, enough bone production in an osteosarcoma to cast the typical radiating shadows, whereas fibrosarcomas with little or no bone production, malignant giant cell tumors, endotheliomas, hemangiomas and multiple myelomas will invade the surrounding tissues but fail to show the radiating spicules. The benign giant cell tumors exhibit the well known coarse trabeculation with expansion of the intact cortex, while the multiple myelomas show widespread destruction and crumpling of the bone with no remaining evidence of the medullary cavity in the portion involved. The so-called malignant giant cell tumors, the multiple myelomas and the metastatic carcinomas most often cause widespread areas of destruction in remotely distributed portions of the skeleton, those of the metastatic carcinomas being particularly discrete.

A meningioma in a subject with osteitis deformans may only with difficulty be distinguished from osteosarcoma of the skull, for the osteitis may so dominate the roentgenogram that the complicating overgrowth or destruction due to the tumor is obscured. Clinical symptoms and signs may be indecisive, leaving the diagnosis to operative or post-mortem examination. Kennedy<sup>12</sup> has recently presented before the New York Neurological Society a patient with a tumor arising from the inner table of the skull, compressing or invading the brain and causing cerebral symptoms. There was a large left frontal prominence, and the roentgenogram showed the typical appearance of Paget's disease. It is probable that this patient, like the fourth in Sir James Paget's original paper,<sup>13</sup> had a meningioma complicating osteitis deformans.

Multiple irregular bosses on the skull added to the generalized thickening of osteitis deformans should suggest superimposed syphilis or tumor. The diagnosis will rest on further evidence of syphilis, the progress of the disease and the therapeutic test.

It is well to bear in mind that chronic infectious processes, including syphilis, occasionally occur in and around bone, closely simulating sarcoma both clinically and pathologically.

#### COMMENT

The malignant tumors in the cases reported were all fibrosarcomas with varying amounts of bone production and foreign body or tumor giant cell reaction. Instances of benign giant cell tumor arising in Paget's disease have not been found, and none are so recorded at the Registry of Bone Sarcoma.<sup>10</sup>

12. Kennedy, F.: A Case of Paget's Disease of the Skull, Assuming a Malignant Character, *Arch. Neurol. & Psychiat.* **11**:599 (May) 1924.

13. Paget, Sir James: On a Form of Chronic Inflammation of Bones (Osteitis Deformans). *Med. Chir. Tr.* **60**:37, 1877.

and moderately tender. Muscle spasm at the shoulder girdle was extreme. Roentgenograms showed involvement of the skull, tibiae, femora, pelvis, spine, humeri, ribs, scapulae and clavicalae by Paget's disease. In the upper third of the right humerus was a destructive process which appeared to have arisen in bone affected by osteitis deformans. (The roentgenograms are not suitable for reproduction.)

In spite of two roentgen-ray treatments, the patient became weak and emaciated, developed a cough and pneumonia and died. Autopsy showed widespread Paget's disease and an osteosarcoma of the upper portion of the right humerus. The microscopic sections from this case (figs. 14 and 15) have been loaned by Dr. Mallory.

In the next case a primary tumor of the ilium caused death from multiple metastases even involving the skull.



Fig. 13 (case 4).—Characteristic deformity of Paget's disease with the sarcoma at the summit of the right shoulder.

*CASE 5.—Paget's disease for at least three years. Gradual enlargement of the head for one year. Growth of sarcoma of right ilium over a period of nine months. Pulmonary embarrassment. Death. Autopsy. Regional and remote metastases.*

C. D., a locomotive engineer, aged 53, was first seen in 1923, when he complained of attacks of pain in the right flank suggesting renal colic. Roentgenogram showed Paget's disease in the bones of the pelvis.

He returned to work and remained well until February, 1925, when he fell on the ice, striking against his right ilium. From this time he suffered greatly from pain both in this region and down the back of the right thigh and leg. Rapid loss of weight and weakness accompanied the appearance of a firm mass which was not tender. This mass grew, at first slowly, then rapidly, below the crest of the right ilium and extended into the right inguinal and gluteal regions.

The patient's head was now found to be enlarged, squared and roughened, while a hat, comfortable the year before, had become too tight for him. The roentgenograms showed the alterations of Paget's disease in the skull as well



Packard, Steele and Kirkbride's patient,<sup>2</sup> a man aged 62, who had had Paget's disease for years, became afflicted by a tumor of the skull (fig. 24); sections from which showed a "typical giant-celled sarcoma." The tissue consisted of bundles of spindle cells and masses of round cells, but there were also many larger bodies with a single, irregularly staining nucleus and numerous giant cells with five or more nuclei. This was probably a cellular osteosarcoma with marked foreign body and tumor giant cell reaction. The case reported by Heazlit<sup>5</sup> as metastasizing "giant-celled sarcoma" was probably of the same nature, while case 1 of the present series showed a few foreign body giant cells and many true tumor giant cells in a fibrosarcoma; I am inclined to believe that this falls, with case 9, in the same category.

The primary new growth was in the skull in two of the nine cases, in the upper portion of the humerus in one, in both the scapula and clavicle in one, in the ilium in two and in the lower portion of the femur in one.



Fig. 24.—Packard, Steele and Kirkbride's patient. Bowed legs of Paget's disease; sarcoma of frontal bones. (Reprinted from *Am. J. M. Sc.*, 1901, vol. 122, by permission of the authors and publishers.)

The tumors would be expected to arise in any bone in the body just as osteitis deformans may occur in any bone. Metastatic tumor nodules appeared in the skull in two instances.

Eight of the nine cases occurred in males, but uncomplicated osteitis deformans occurs in this sex in only about 65 per cent of cases, and one would expect those complicated by malignancy to correspond.

In eight instances the sarcoma arose in bone markedly affected by Paget's disease, while in one case the underlying disease was not suspected until roentgen-ray examination was made. Thorough roentgenographic study is essential, and, as has been suggested, patients with bone sarcoma, especially when over middle age, should have a roentgen-ray examination of the entire skeleton.

A roentgenogram covering only the field of the tumor may fail to detect Paget's disease, either because the widespread involvement by the sarcoma obscures the osteitis, or because the Paget's disease is so slight in the bone from which the tumor arises as to remain unrecognized.



Fig. 14 (case 4).—The bone of osteitis deformans (typical picture). Methylene blue and eosin stain;  $\times 80$ .



Fig. 15 (case 4).—The sarcoma. Methylene blue and eosin stain;  $\times 80$ .

It is probable, however, even in these instances, that the sarcoma originates from bone affected by Paget's disease (whatever this disturbance may be); otherwise the age grouping is difficult to understand, for it is well known that bone sarcoma is a disease of childhood and early adult life. Gross,<sup>14</sup> in a classical study of bone sarcomas, notes that of thirty-nine cases of periosteal sarcoma, the average age of onset was 23 years, the youngest age 12 and the oldest age 55.

In the present series of sarcomas arising in Paget's disease, the average age of onset of tumor symptoms was 57 years, the youngest 36 and the oldest 69.

The bone sarcomas appear to fall then into two large groups, those of youth, in which the overgrowth arises in developing or healing bone, and, those usually of later life in which the tumor originates from the irritated (?) bone with the altered structure known as a deforming osteitis.

The unfavorable prognosis of all sarcomas of bone is common knowledge. Of the nine patients in the present series, eight are dead and the result in one case is unknown. The condition in case 1 was not relieved by partial removal of the tumor from the skull or by roentgen-ray therapy. In case 2, rapid growth of a sarcoma of the ilium was apparently arrested, and there was partial relief from pain, following intensive roentgenotherapy. Amputation of a humerus affected with sarcoma gave relief from discomfort in case 3. In cases 4 and 5, the patients, treated by roentgen ray alone, were not benefited, while in case 6, temporary respite from the pain of a large sarcoma of the scapula and clavicle was afforded by radical amputation. Two patients treated by local excision and one by radical operation were unimproved and died with metastases. Among the eight instances in which the end-results are known, the average duration of life after the first evidence of malignancy was eight months, the shortest two and one-half months, the longest one year.

It is interesting to note that when three of our patients were originally seen the condition was uncomplicated Paget's disease, and later complicated by sarcoma. Gruner, Scrimger and Foster<sup>3</sup> were impressed in their case, as they might well have been, by the "step-like changes in the bones from an apparently simple process (osteitis deformans) to one of diffuse malignancy." This occurred in a man, aged 56, while under observation in the hospital, severe pains in the right arm and shoulder being superimposed on the "rheumatic" pains of an old osteitis deformans. Three months later, swellings appeared over the right shoulder and radius, and the radius fractured spontaneously. Resection at the

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14. Gross, S. W.: Sarcoma of the Long Bones: Based on a Study of One Hundred and Sixty-Five Cases, *Am. J. M. Sc.* 78:2, 1879.

as in the pelvis. In the cranial roentgenogram were seen two or three small, round, punched-out areas suggestive of metastases (fig. 16), and in the right ilium there was disclosed a large area of destruction interpreted as sarcoma (fig. 17).

Four intensive roentgen-ray treatments failed to relieve the discomfort, and a persistent cough with marked dyspnea appeared, followed shortly by the removal of several liters of bloody fluid from the pleural cavities.

Necropsy disclosed widespread sarcomatosis. A large tumor had arisen from and partially destroyed the right ilium; invading the right inguinal region and the right side of the pelvis. The growth extended along the retroperitoneal and portal lymph channels and involved the omentum, stomach and liver. Metastases were present in the pleural cavities and lungs while in the calvarium were several sharply punched-out defects filled with tumor of a similar nature.

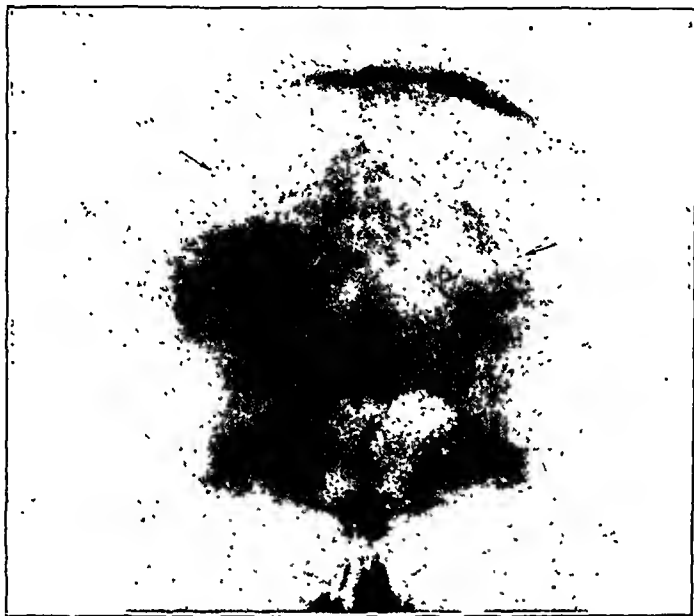


Fig. 16 (case 5).—Paget's disease with small punched-out areas caused by metastatic nodules of sarcoma in the calvarium.

The microscopic sections showed osteogenic sarcoma, in the original tumor and in the metastases, and bone from the skull exhibited the characteristics of osteitis deformans (fig. 18).

In the following case, the youngest person in the series, the disease is first recorded as having been present at the age of 16. The bones about the shoulder joint were involved in the tumor, and there were terminal metastases to the skull.

*CASE 6.—Osteitis deformans for twenty years. Sarcoma of clavicle. Amputation at shoulder girdle with relief from pain. Death from pulmonary and cranial metastases in three months.*

J. M., an Irish-American shoemaker, aged 36, came to the outpatient department in 1914 complaining of pain in the right shoulder following slight trauma. Roentgenograms showed the changes of Paget's disease in many of the bones of the body.

shoulder girdle was ineffective, metastatic tumor nodules appearing in the skull coincident with the rapid decline of the patient. Autopsy showed widespread osteosarcomatous lesions together with the typical gross and microscopic appearances of osteitis deformans.

In only one instance was there a history of syphilis (case 4). The patient had had a chancre and a rash, and the blood Wassermann reaction was strongly positive, but physical signs of syphilitic infection were not present. The evidence of Paget's disease was unmistakable (figure 15), although the patient may also have had syphilis.

#### SUMMARY

The files of the Peter Bent Brigham Hospital, the Boston City Hospital, the Massachusetts General Hospital and the Huntington Memorial Hospital contain, so far as can be determined, case histories of sixty-four examples of Paget's disease of the bones.

In five of these cases, a sarcoma had arisen in bone involved in osteitis deformans, as verified by the pathologic examination of operative or postmortem tissues. (Three other cases from the Registry of Bone Sarcoma and two from the above institutions doubtless represent additional instances of the combined disorder.)

The incidence of sarcoma in Paget's disease, therefore, so far as it is represented among hospital patients in this country, would be approximately one in ten, a sufficiently high percentage to excite surprise in view of the age of these patients and the fact that bone sarcoma is considered to be a disease of youth.

In elderly people afflicted with sarcoma of bone roentgenograms of the entire skeleton should always be taken, for it is probable that the coexistence of the osteitis deformans of Paget is frequently overlooked.

last picture of two years before: the bone was larger and thicker and the density seemed not quite so marked; instead of the periosteal line of the bone being intact, there were a few erosions in one area—a few indentations in the normal outline. Apparently, there was a small amount of new bone production beyond the normal line. The picture did not permit one to make a diagnosis of sarcoma, although it was more suggestive of sarcoma than the earlier pictures.

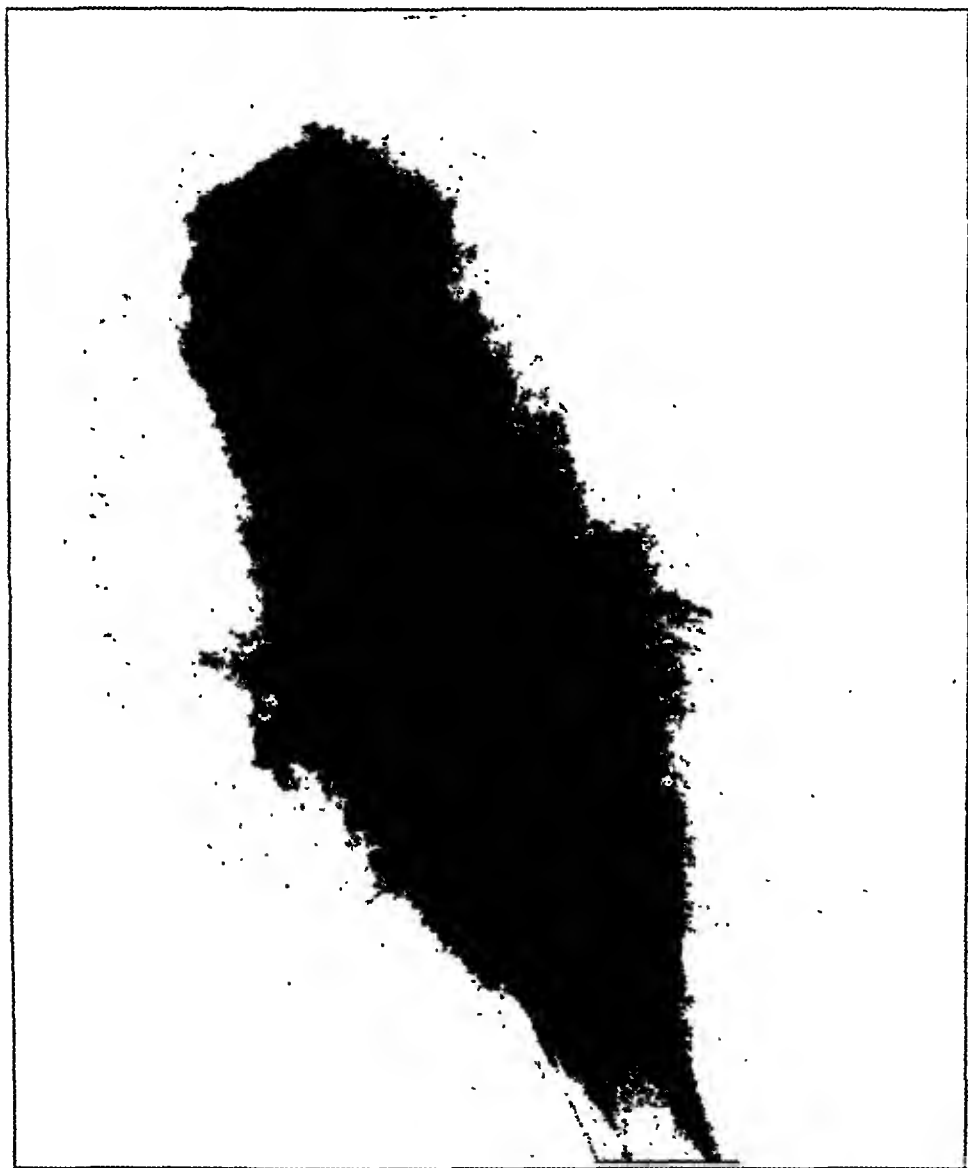


Fig. 59 (case 133 in table 7).—After two months' treatment with high voltage roentgen rays. The patient died a few months later of lung metastases.

An exploratory operation was performed, March 16, 1925. When the muscle was cut through, some soft, vascular tissue was found which had broken through the periosteum. There was some discussion at the time as to whether this was tumor tissue or the product of an old inflammatory process; some of it was taken for culture and section. The periosteum around the bone was thickened and a section of this also was taken for examination. The microscopic diagnosis of

Dr. F. M. Jeffries was mixed cell sarcoma; that of Dr. James Ewing, osteogenic, polygonal cell, malignant sarcoma.

The patient was put on the mixed toxins, April 1, and the dose daily increased up to the point of producing a marked reaction. Immediate improvement, was noticed. The pain disappeared, the tumor steadily diminished in size, and examination in the early part of July, 1925, showed him in excellent local and general condition. He has gained 17 pounds (7.7 Kg.) in weight, and is able to walk about with an apparently normal leg. The improvement in his local condition was further confirmed by recent roentgenograms. The patient was still well when examined in July, 1926.

*CASE 36.—Periosteal round cell sarcoma of clavicle; total excision followed by toxin treatment; patient well fifteen and one-half years later; probably endothelioma.*

J. V., a boy, aged 16 years, with a negative family history, in the beginning of October, 1909, while going down stairs, tripped and in trying to save himself caught hold of the banister with his left hand, bringing himself to a sudden stop with a severe jerk. This caused a good deal of strain on the left shoulder and clavicle. Shortly after this he was riding a motorcycle, which broke down; he was obliged to tow it for a distance of ten miles, using his left hand almost entirely to do the towing. In the end of October, he first felt pain and soreness in the region of the left clavicle, and one week later a swelling was noticed at this site. November 20, he consulted Dr. Alfred Potter of Brooklyn, who found a fusiform enlargement of two thirds of the inner portion of the shaft of the left clavicle. Roentgenograms were taken which showed a typical periosteal sarcoma; the outline of the periosteum was nearly lost.

The patient was referred to us, and from the clinical and roentgen-ray evidence, we made a positive diagnosis of periosteal sarcoma, and urged an immediate removal. At this time the tumor was about the size of an English walnut, there were no enlarged glands, little pain, and he was in excellent general condition. November 22, with the assistance of Dr. William A. Downes, we performed a total excision of the clavicle as follows: An incision was made over the outer surface of the clavicle over its entire length. After we had separated the periosteum and the bone, a Gigli's wire saw was passed beneath the clavicle  $1\frac{1}{2}$  inches (3.7 cm.) from the outer extremity, well beyond the tumor. The inner and larger portion was then lifted up and dissected from the subclavian muscle and separated from its attachments until the sternocostal articulation was reached; disarticulation was then accomplished with little difficulty and no hemorrhage. The outer portion of the clavicle was removed with a Rongeur forceps. The microscopic diagnosis of Dr. James Ewing was periosteal round cell sarcoma (myeloma).

The patient made an uninterrupted recovery, the wound healing by primary union. Before his discharge from the hospital on the tenth postoperative day, the mixed toxins were begun; these were later given at home for a period of three months by his family physician. Almost no deformity resulted from the operation and the patient retained complete functional use of his arm. He served in the army in France during the war. At the present time, fifteen and one-half years later, he is in excellent condition with no evidence of a recurrence. We believe this case to have been one of endothelial myeloma. There were no giant cells and the tumor was laminated without new bone production.

# PREVENTION OF REGENERATION OF THE RIBS

## A PROBLEM IN THORACIC SURGERY

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Since the original experiments of Duhamel, a voluminous literature on the regeneration of bone has accumulated. It has dealt chiefly with the nature of the process, the elements of normal bone from which the new is formed and the bearing of these questions on the problems encountered by the orthopedic surgeon. Because of the nature of these problems, interest has been centered on means of assuring regeneration after operation, of stimulating it after fractures, and explaining why it does not occur in some cases. The occasions in which its prevention has been desirable have been few or none.

In thoracic surgery, however, in which the bony ribs are encountered chiefly as a hindrance to exposure and collapse, the prevention of their regrowth is frequently desirable. This is the case in drainage operations (empyema and abscess of the lung), in operations performed in stages, and in cardiolysis and the operation for dilated thorax, in which a permanent mobilization of the wall of the chest is the end sought.

In resection of a rib for empyema, the rapid regeneration of bone is the principal factor in closing the opening and in preventing efficient drainage. In cases of abscess of the lung reoperations for widening the fistula are frequently necessary for the same reason. The chief advance in thoracic surgery in recent years, the one which has tended most to lower the mortality and extend the indications, is the multiple stage operation. Whenever this must be performed over a period of weeks or months, the later stages are complicated and made doubly difficult because the reformed ribs must be resected, either to maintain exposure or to assure collapse. In the Graham multiple stage cauterization lobectomy the exposure is thus frequently compromised, and in the Estlander procedure for chronic empyema and in all of the extrapleural thoracoplasties employed in pulmonary tuberculosis and bronchiectasis, efficient collapse is frequently prevented by regeneration of the ribs resected at the early stages. In these operations the true collapse occurs only with the removal of the last ribs. Until then the part of the wall of the chest which is already mobilized hangs from the ribs like the curtain of a tent, and, if the bones reform in this position, the final collapse is compromised.



The importance of this is evident. In previous publications,<sup>6</sup> we have shown that the fatal absorption of toxins from an obstructed bowel occurs as a direct result of gangrene in the wall. Necrosis of the bowel is therefore the chief factor in making intestinal obstruction a desperate surgical emergency. This process must be arrested early or death is inevitable.

#### SUMMARY

Gaseous distention of the bowel alone may exert sufficient pressure to produce gangrene by occlusion of the circulation in the bowel wall.

This mechanism operates most completely along the antimesenteric surface of the intestine. The resultant gangrene is most apparent in that area.

The experiment with the gas trap mechanism offers an explanation of the conditions leading to incarceration and strangulation of the bowel.

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6. Gatch, W. D.; Trusler, H. M., and Ayres, K. D.: Acute Intestinal Obstruction; Mechanism and Significance of Hypochloremia and Other Changes in Blood Chemistry, *Am. J. Med. Sc.*, to be published.

The operation of cardiolysis and that for dilated thorax are frequently only temporarily successful, because the mobilization lasts only until the ribs have regenerated.

Heretofore, when for any reason reformation of the ribs was not desired, it has been the custom to resect the periosteum with the bone. This accomplishes the result, but adds greatly to the risk of the operation. Between the posterior layer of the periosteum and the pleural cavity lie only the thin endothoracic fascia and the parietal pleura. To remove the periosteum without breaking through these and opening the pleural cavity is difficult. If this is done, the postoperative course is complicated by a pneumothorax and, if the wound becomes infected, frequently by an empyema.

It seemed probable that regeneration of the ribs could be prevented by destroying chemically the inner, and supposedly the bone-forming, layer of the periosteum. In this article it would be beside the point to discuss the difficult and still unsettled problem of the manner in which the bone reforms after subperiosteal resection. Opinion is divided between the periosteal theory of Duhamel and Ollier and the "bone-chip" theory of MacEwen. According to the former, the cambium layer of the periosteum has an osteogenetic function. MacEwen, on the other hand, believes that the periosteum is merely a limiting membrane and that, after supposedly subperiosteal resection, bone reforms only because cells and chips of the cortex have been left in place. Practically, it is important only that the bone does regenerate.

The problem was whether or not some chemical cauterizing agent could be found which, on application to the inner layer of the periosteum, would destroy the bone-forming elements without producing deep necrosis and perforation of the pleura.

To test this the following experiments were carried out. Segments measuring from 6 to 8 cm. were resected subperiosteally from two or three adjacent ribs in dogs. The lower periosteal beds and cut ends of bone were painted with different chemicals, the upper ones being left as controls. The cauterizing agents used were (1) silver nitrate stick, (2) 50 per cent silver nitrate solution, (3) concentrated solution of chromic acid and (4) Zenker's solution.

#### RESULTS WITH THE VARIOUS CAUTERIZING AGENTS

*Silver Nitrate Stick.*—The silver nitrate stick was found to produce too extensive a necrosis. The first dog on which it was used was found dying on the fifth day after the operation. The cauterization had produced a wide perforation of the pleura, the wound had become infected and separated and an open pyopneumothorax was present (fig. 1). The same sequence of events occurred in several other cases. A dog which

# RELATION OF NITROGEN BODIES OF BLOOD TO SURGICAL PROBLEMS IN LIVER AND IN BILIARY TRACT DISEASE

## II. STATUS OF NITROGEN BODIES OF BLOOD IN EARLY, MILD AND MODERATELY ADVANCED CASES OF BILIARY TRACT DISEASE \*

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The liver is known to be the seat of much of the intermediary nitrogen metabolism in the body. During the last two decades, much has been written concerning the urinary nitrogen partition in hepatic disease. Rowntree, Marshall and Chesney emphasized the difficulty of interpretation in such studies and called attention to the accompanying changes in the blood. They found that the proportion of blood urea was slightly decreased in hepatic disease. More recently, Bollman, Mann and Magath have reported evidence pointing to a cessation of urea formation in dogs after complete extirpation of the liver. In man, a comparable degree of hepatic insufficiency is not observed, even with the grossest hepatic changes. In experimental animals with obstructive jaundice, Greene showed that there was usually a sharp and definite decrease in both the relative and absolute values of the blood urea. These low values persisted until shortly before the death of the animal, when a terminal rise of blood urea occurred. This probably was evidence of terminal renal insufficiency.

I shall discuss the clinical side of the relationship of the nitrogen metabolism and blood nitrogen retention to surgical disease of the liver. Cases of biliary tract disease have seemed of most promise and have been employed.

For the purpose of this study cases of biliary tract disease, including in this general classification all cases of cholelithiasis, cholecystitis and cholangitis, have been classed into: group I, early and moderately early cases without jaundice or other complication; group II, early and moderately early cases with jaundice; group III, early and moderately early case with and without jaundice and with nephritis and group IV, late cases of advanced biliary tract disease with deep jaundice, clinical signs of cholangitis and with and without secondary change in the kidneys.

The cases studied were not selected in any way but were studied seriatim as the patients were admitted and discharged from the hospital. In all of the studies special attention was paid to the surgical problems involved.

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\* From the Mount Sinai Hospital.

had not shown ill effects was killed two weeks after operation, another three weeks, and still another four weeks, after operation. Autopsy at two weeks showed that the wound was clean, but there was a wide opening through the rib bed and the parietal pleura. At three and four weeks the pleura was not perforated, and the bone had not regenerated. It seems probable that there had been openings, but that they had closed by granulation.

From these experiments it was obvious that the silver nitrate stick was not a suitable agent, since it caused a complete sloughing away of the rib bed and pleura and, when the wound became infected, an empyema.



Fig. 1.—Section of wall of the chest, showing perforation of the periosteum bed and parietal pleura following cauterization with a silver nitrate stick.

*Silver Nitrate 50 Per Cent.*—Six dogs were operated on, and the lower rib bed was painted with 50 per cent silver nitrate solution. In one instance the wound became infected, and the pleura was perforated. In none of the others was there regeneration in the painted rib bed.

The one instance of perforation of the pleura indicated that there is danger in the use of this solution.

*Concentrated Solution of Chromic Acid.*—Four dogs were operated on, and the lower rib bed was painted with a concentrated solution of chromic acid. In none of these was there evidence of perforation of the pleura. Autopsies were performed on the dogs at the end of one, two, three and four weeks, respectively. In all the dogs, there was definite regeneration of bone in the control and none in the painted bed. In

The following tables list the general facts with special reference to the study of the blood chemistry. The tables follow the classifications made previously.

TABLE 1.—*General Table of Cases of Biliary Tract Disease of Mild and Moderate Grades Without Jaundice or Other Extraordinary Liver Complication, Without Demonstrable Kidney Involvement and Without Any Other Complication\**

Case	Age	Condition	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
1	58	Chronic	12.6	26.7	2.0	1.0
2	41	Acute	12.6	32.2	2.5	1.0
3	27	Chronic	12.6	34.1	1.9	1.0
4	..	Acute	12.6	39.9	1.3	1.1
5	45	Acute	16.2	45.1	2.1	1.4
6	42	Acute	11.5	33.0	1.6	1.1
7	..	Chronic	12.6	43.3	2.2	1.2
8	28	Chronic	14.0	47.6	3.2	2.0
9	26	Chronic	14.0	44.9	...	...
10	48	Chronic	14.0	44.4	1.2	1.5
12	37	Chronic	14.0	35.9	2.2	1.2
13	40	Chronic	14.0	51.6	5.0	1.7
14	45	Chronic	14.0	42.0	2.5	1.9
15	35	Chronic	14.0	35.8	3.1	1.7
16	24	Chronic	14.4	35.0	2.2	1.5
17	35	Acute	12.6	45.4	4.1	2.1
18	28	Chronic	14.0	34.1	1.2	1.8
20	..	Chronic	14.0	31.5	2.8	1.0
21	..	Acute	15.0	34.1	2.0	1.0
22	50	Chronic	14.6	32.3	3.1	1.1
24	32	Chronic	14.0	32.6	3.5	1.1
25	40	Chronic	12.6	28.0	2.5	1.0
28	43	Chronic	14.6	36.7	3.0	1.0
30	44	Acute	14.0	33.0	2.5	1.0
32	32	Acute	14.0	40.0	1.5	0.9
35	..	Acute	16.8	...	3.5	1.1
36	34	Chronic	16.8	45.5	2.5	1.3
37	21	Chronic	16.8	36.7	2.0	1.4
38	30	Chronic	16.8	44.4	1.7	1.2
40	19	Fistula	16.8	39.6	...	...
42	33	Chronic	16.8	38.5	2.0	1.8
43	18	Chronic	18.2	35.6	1.8	1.4
45	42	Chronic	18.2	31.2	1.7	1.1
46	46	Chronic	18.2	32.5	2.7	1.4
47	48	Chronic	16.8	32.2	1.8	1.3
48	47	Acute	18.2	36.8	1.7	1.2
50	34	Chronic	16.6	45.4	1.8	1.4
53	34	Chronic	16.8	41.0	...	...
54	..	Chronic	18.2	37.6	1.8	0.9
55	18	Chronic	18.2	36.7	2.6	1.0
57	32	Acute	12.6	17.9	2.5	1.0
60	..	Chronic	15.4	34.1	2.5	1.0
62	47	Chronic	16.8	44.4	2.6	1.0
64	31	Acute	15.4	36.7	2.0	1.2
65	31	Chronic	15.4	32.9	1.9	1.0
66	26	Acute	15.4	37.0	2.3	1.0
68	35	Chronic	19.6	37.0	2.5	1.2
69	..	Chronic	21.0	42.4	2.5	1.1
70	40	Acute	22.4	42.5	2.5	2.2
71	30	Chronic	21.0	40.9	...	...
72	..	Chronic	21.0	42.2	2.7	1.5
74	36	Chronic	21.0	36.7	4.0	2.6
75	38	Acute	22.4	44.4	2.0	1.0
76	..	Chronic	22.4	42.5	2.0	1.0
77	..	Chronic	22.4	42.5	2.2	1.2
78	..	Chronic	22.4	42.5	1.7	1.2
79	4	Acute	22.4	37.0	2.5	1.6

\* All of the patients in this series had the following table of comparative observations on comparative observations were made from samples of blood secured in the morning before any food was taken.

all specimens the painted bed was freely flexible, and without effort could be wrinkled up so that the ends of the bone could be approximated. In the control beds there was definite stiffening and resistance to bending. This was present in the one week specimen. At four weeks there was a definite willowy new bone and marked resistance to bending. Both the three and four week control specimens had to be decalcified before they were sectioned.

*Zenker's Solution.*—Six dogs were operated on, and the lower rib bed was painted with Zenker's solution. Several of them were operated on again after a week's interval, and the same procedure was carried out on the opposite side. In none of these dogs was there any perforation of the pleura or regeneration of bone in the painted bed. Specimens



Fig. 2.—Section of the wall of the chest, showing pleural face of two ribs, portions of which had been sectioned. The regeneration in the upper control bed is evidenced by the white callus. Its absence in the lower bed in which the periosteum had been painted with Zenker's solution is proved by the lack of callus and the puckering of the pliable tissue. This specimen was removed four weeks after the resection of the ribs.

were removed, one, two, three and four weeks after operation and the final one six weeks after operation. In all instances the painted rib beds remained easily pliable so that they could be wrinkled up and the cut ends of the rib could easily be approximated. The control beds were the same as in the chronic acid series. The accompanying photograph (fig. 2) of a specimen preserved in Kaiserling solution shows abundant growth of callus in the control. Absence of callus and the pliability of the painted bed is evidenced by the puckering incident to the postmortem contraction. Figure 3 shows a roentgenogram of the four weeks specimen. In this experiment the middle bed and the

## ANTEOPERATIVE OBSERVATIONS

A summary of the facts to be deduced from this table includes the following:

1. For the most part the figures run within the "normal" ranges but figures are also found at both the upper and lower limits of the "normal." As all of these blood figures are dependent on the diet of the person at the time of the blood examination, the figures at the opposite extremes of the scale must be accepted as "normals" in the absence of other data which might indicate any abnormality outside of the biliary tract.

2. The relation of the blood urea to the nonprotein nitrogen of the blood is not of a proportionate degree. The proportions of either are variable and independent of each other. The general tendency, however, is for the urea and nonprotein nitrogen figures to be complementary.

3. The figures for the uric acid content of the blood show a wide variation. The figures do not show a proportionate relationship of the blood uric acid to the blood urea, blood nonprotein nitrogen or blood creatinine, either in any individual case or from case to case. For a similar reason, all of these figures must be accepted as "normal" in each particular case and in the group as a whole.

4. The creatinine content of the blood shows the greatest constancy. The figures do not show a proportional or other relationship to the other blood figures and seem to indicate that their origin is in some way independent of the origins of the other blood constituents. They seem to indicate that the creatinine metabolism is not disturbed in cases of biliary tract disease; the small variations in the blood figures seem to confirm the prevalent belief that the creatinine content of the blood represents wear and tear of body tissues, and, except in rare instances, it is independent of the wide fluctuations of the food supply.

5. The age of the patient and the blood figures taken as a whole or in any one of its particulars, are not related. As most of the patients with biliary tract disease are women, almost all of the observations reported in this article were made on women.

6. The acuteness or chronicity of the pathologic lesion is not related to the variations found in the blood figures. This statement does not refer to far advanced cases of biliary tract disease.

7. In a general way, one can conclude from these observations that in mild and moderate grades of biliary tract disease, without jaundice, without nephritis and without other complications, the urea, nonprotein nitrogen, uric acid and creatinine contents of the blood are within the normal ranges, and their variations are dependent on the dietary characteristics of the individual at the time of observation.

Table 2 contains the cases of this series in which the patients had jaundice. An attempt is made to indicate the depth of the jaundice by the figures representing the concentration of the cholesterol content of the blood serum and by the quantitative estimations of bilirubin content

upper half of the lower bed were painted. There was good regeneration of the upper rib and of the lower half of the lowest rib.

The results with chromic acid were satisfactory. With the Zenker's solution they were equally good if not better, and, since this is much the weaker caustic, it seems the preferable one. It is probable that anything that will kill the superficial cambium layer of cells will prevent bone regeneration and that even weaker fixatives would be satisfactory. There is not, however, any contraindication to the use of Zenker's solution. It accomplishes the desired result, and is something which is always on hand or easily obtainable.

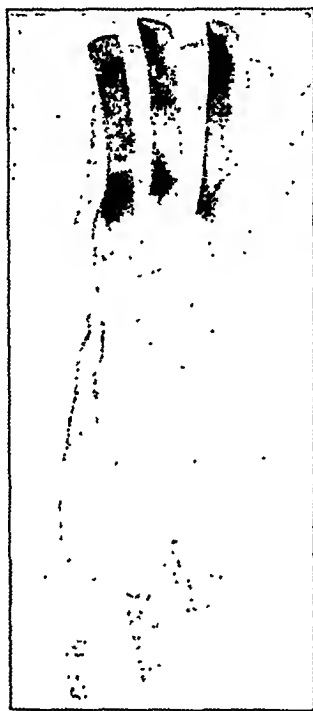


Fig. 3.—Roentgenogram of specimen removed four weeks after resection of segments of three ribs. The periosteum of the resected portion of the middle rib and the upper half of the periosteum of the resected portion of the lower rib were painted with Zenker's solution. There is good regeneration in the upper control bed and in the lower half of the lowest bed.

In the Sauerbruch extrapleural thoracoplasty as used for pulmonary tuberculosis and for bronchiectasis, the method is contraindicated. In these conditions, in which the mediastinum is not fixed and the lung is not contracted, destruction of the periosteum by producing a permanent mobilization of the wall of the chest, would occasion paradoxical breathing in the collapsed lung, and consequently cause a reduction of the already seriously compromised vital capacity.



of the blood serum according to the van den Bergh test. It was shown in a previous study<sup>1</sup> that a high cholesterol content of the blood is not a constant phenomenon in conditions accompanied by jaundice, although usually high figures are obtained; with this reservation, the figures given in table 2 for the blood cholesterol contents can be accepted for the purpose indicated. The van den Bergh reaction in its quantitative form is a constant phenomenon and forms a valuable criterion for the purpose of estimating relative depths of jaundice as observed from day to day or in comparative series. The estimations have sufficient accuracy for practical purposes.

The chief deduction to be made from this table is that varying degrees of jaundice in the absence of kidney complications apparently do not influence and do not have a proportional relation to the blood figures for urea, nonprotein nitrogen, uric acid and creatinine. The

TABLE 2.—Cases of Mild and Moderate Grades of Biliary Tract Disease With Jaundice but Without Demonstrable Kidney Involvement or Other Complication

Case	Age	Condition	Van den Bergh	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine	Cholesterol
31	28	Chronic	.....	10.0	32.0	2.1	1.0	0.46
39	29	Chronic	.....	16.8	29.1	1.7	1.2	.....
41	32	Chronic	.....	15.4	34.4	2.2	1.8	0.230
42	49	Chronic	.....	15.4	28.9	2.5	1.5	0.260
49	54	Chronic	.....	18.2	62.9	4.1	1.2	0.260
51	69	Chronic	.....	26.8	71.7	2.1	1.5	0.512
57	63	Chronic	1:1,000,000	14.0	57.2	2.5	1.1	0.170
56	48	Acute	1:100,000	9.8	.....	1.5	1.1	0.142
61	25	Chronic	1:100,000	15.4	25.8	2.0	1.0	0.660
81	32	Acute (1st attack)	1:150,000	10.0	.....	2.7	1.2	0.160
88	30	Chronic	1:120,000	18.2	57.2	2.2	1.0	0.102
82	40	Acute	1:120,000	26.6	29.0	2.5	1.0	0.120
89	35	Chronic	1:20,000	15.4	34.1	2.5	1.0	0.100

figures for the latter do not differ materially from those given in table 1 and are within the normal ranges. The relatively "normal" range of the blood figures most probably have important relations to the comparatively short duration of the jaundice, to its comparative mildness and to the compensatory mechanism of the body.

Cases 49 and 83 need some explanation. Case 49 shows figures for the blood nonprotein nitrogen and for the blood uric acid at the upper limits of the normal. The association of high uric acid figures most likely indicates that the excess is derived from a similar excessive proportion of nitrogenous food in the diet. Case 83 does not have this association of a high uric acid content of the blood, but nevertheless a similar explanation is probably correct for the high urea and non-protein nitrogen content of the blood.

1. Wilensky, A. O., and Rothschild, N. A.: *Am. J. M. Sc.* **156**:239 (Aug.) 1918; **156**:404 (Sept.) 1918; **156**:564 (Oct.) 1918.

In spite of the accepted relationship between distention and circulatory changes in the intestine, we were unable to find in the literature any actual measurement of this ratio. The nearest approach is the observation of Van Zwahlenburg,<sup>4</sup> who studied microscopically, by means of a light within the lumen of the intestine, the actual effects of distention on the blood flow. He observed that at a pressure of 30 mm. of mercury some capillary streams were arrested; at 60 mm., small veins were arrested, and in most veins the current was slow; at 90 mm. all blood streams were moving slowly and many but not all, currents were changing direction frequently; at 130 mm. pressure, all circulation ceased, and there was some oscillation of corpuscles but no progress; some ecchymotic hemorrhages were seen with the pressure as low as 50 mm.; pressure maintained at from 80 to 90 mm. of mercury for one hour caused the appearance of congestion, with the vessels engorged and the circulation slow.

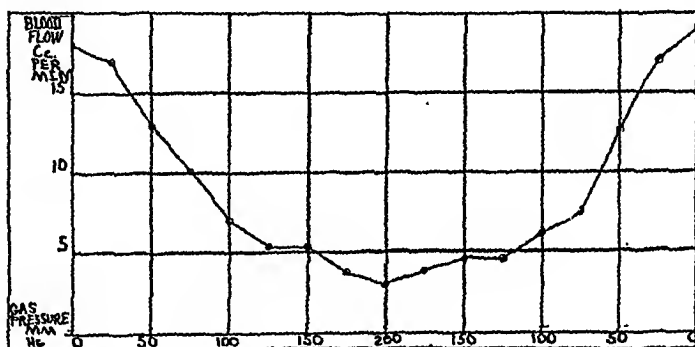


Fig. 1.—Curve showing the average readings of blood flow in cubic centimeters per minute through the intestinal wall under varying degrees of gas pressure in the lumen.

In view of the foregoing facts, we have measured the volume of blood flow through loops of intestine under different degrees of distention.

#### METHOD OF DETERMINING BLOOD FLOW

Dogs were used in all determinations. Under morphine and ether anesthesia the abdomen was opened and a loop of small intestine was withdrawn, its vein isolated and a cannula inserted. Both ends of the loop were then closed by clamp and ligature, so as to cut off anastomotic blood supply as well as to close the lumen of the gut. By this procedure we were provided with an obstructed loop of bowel, with normal relationship to the arterial circulation, from which all the venous return could be collected and measured. Every precaution was taken to keep the tissues moist and warm.

We first attempted to prevent blood clots in the cannula by coating the inside with paraffin. Measurements were made of the volume of the flow of blood per

4. Van Zwahlenburg, C. V.: Strangulation Resulting from Distention of Hollow Viscera, *Ann. Surg.* 46:780 (Nov.) 1907.

The nephritis in the cases included in table 3 was mild. The examination of the urine showed the presence or absence of an albuminuria of the mildest character and the presence of a minimal number of hyaline or granular casts. There was never any bloody or smoky urine or other signs of an acute kidney process or of an acute exacerbation of an old process, and, except for the results of urinalysis, the presence of a renal lesion would not have been suspected. Such forms of nephritis are characterized by little if any disturbance of function and by no disturbance of the nitrogenous metabolism.

The chief deduction to be drawn from this table is that such mild cases of nephritis occurring either as a complication or as an associated phenomenon in biliary tract disease do not manifest any increase of the

TABLE 3.—Cases of Mild and Moderate Grades of Biliary Tract Disease With and Without Jaundice and With Nephritis but Without Other Complication

Case	Age	Condition	Jaundice	Van den Bergh	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine	Cholesterol
24	32	Acute	Absent	.....	14.0	33.3	3.1	1.1	0.176
52	48	Chronic	Absent	.....	15.4	49.0	2.0	2.0	0.296
76	64	Chronic	Absent	1:400,000	21.0	35.0	3.5	1.1	0.160
81	45	Acute	Absent	.....	29.4	57.7	3.3	1.0	0.142
25	38	Chronic	Present	.....	12.6	32.6	2.5	1.1	0.245
66	26	Acute	Absent	.....	15.4	35.0	2.3	1.2	0.110
67	47	Chronic	Absent	.....	15.4	30.0	3.0	1.1	0.130
75	..	Cholangitis	Absent	.....	21.0	60.0	2.2	1.1	0.140

TABLE 4.—Cases of Biliary Tract Disease with Demonstrable Structural Liver Change

Case	Liver Change	Nephritis	Jaundice	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine	Cholesterol
4	Infiltration.....	Absent	Absent	12.6	30.9	1.3	1.1	0.100
80	Degeneration.....	Present	.....	29.4	....	5.3	2.0	0.142 died
75	Chronic cholangitis	Present	.....	21.0	60.0	2.2	1.1	0.140 died
55	Infiltration.....	Absent	Absent	18.2	36.7	7.6	1.0	0.112
60	Cirrhosis.....	.....	.....	15.4	34.1	2.5	1.0	0.176
85	Necrosis.....	Absent	Present	18.2	35.0	4.0	1.1	0.112
86	Chronic cholangitis	Absent	Absent	19.6	45.5	3.5	1.2	0.154
90	Fat infiltration....	Absent	Present	14.0	35.0	2.8	1.3	0.248
91	Chronic cholangitis	Absent	Present	18.2	3.5	3.5	1.2	0.260

urea, nonprotein nitrogen, uric acid and creatinine content of the blood. The figures for the latter are not different from those in the uncomplicated forms of mild or moderately severe biliary tract disease.

In these cases structural change in the liver tissue was demonstrable. Except for the fact that the figures show a tendency to group themselves toward the upper limits of the "normal" range, not any particular change is noted. This is most likely due to the enormous compensatory capacity of the liver. The highest figures are present when the biliary tract disease is complicated by renal changes. The occurrence of upper limit level figures in cases 80 and 85 for the blood content of urea and uric acid possibly is suggestive of the work of Bollman, Mann and Magath.

minute, while the intestinal loop was inflated to various degrees of gas pressure through a needle connecting with a large bottle, which acted as a reservoir of compressed air. The system was provided with a mercury manometer to indicate the pressure. Despite the coating of paraffin, some difficulty was encountered, due to the clotting of blood in the cannula, causing partial or complete obstruction to the flow. For this reason we have relied only on those experiments in which, after release of the pressure in the bowel, the rate of blood flow returned approximately to the rate before distention. This served also as a check on the maintenance of blood pressure. In two or three instances blood pressure readings were made by means of a carotid cannula and manometer, but this was not considered necessary later, for we found that the pressure remained fairly constant in spite of the blood necessarily lost in the experiment.

On account of the difficulty encountered by the clotting of the blood, a cannula was devised with an upright side tube joining at the point of entrance of blood from the vein. The neck of the side tube was drawn down to a small capillary.

*Determination of Blood Flow Through Isolated Loops of Small Intestine Under Various Degrees of Gas Pressure*

Pressure in Mm. of Mercury	Blood Flow in Cubic Centimeters per Minute						Average
	A	B	C	D	E	F	
0	20	20	21.0	12.0	10.0	10.0	18.0
25	20	..	18.0	20.0	11.2	16.0	17.0
50	14	8	18.0	16.0	10.0	12.0	13.0
75	12	..	13.0	10.2	7.8	7.6	10.1
100	8	4	10.0	7.0	6.8	6.0	7.0
125	6	..	7.5	5.2	4.4	3.6	5.1
150	6	4	5.6	4.2	4.0	3.6	5.1
175	..	..	4.0	....	3.6	3.6	3.7
200	4	2	....	....	....	....	3.0
175	4	..	4.0	....	3.6	3.6	3.7
150	8	4	4.0	4.2	4.0	3.6	4.6
125	..	..	5.0	4.8	4.8	3.6	4.6
100	10	6	5.6	6.0	5.6	4.0	6.2
75	..	..	8.6	7.0	6.0	6.2	7.5
50	14	18	12.0	11.6	10.0	10.6	12.6
25	22	..	18.0	16.4	12.0	16.0	17.0
0	28	22	24.0	19.6	8.0	18.0	19.0

Through this upright tube a constant flow of 10 per cent sodium citrate solution was maintained. This was found to flow at the rate of 0.5 cc. per minute, and this amount was deducted from the readings of the blood flow. The results of the measurements in several experiments are tabulated, with readings taken as the pressure increased and again as it decreased. The graphic record is a composite curve, derived by averaging the readings for each pressure.

## RESULTS

It will be noted that for each increase in gas pressure within the intestinal lumen there is a corresponding decrease in the volume of blood per minute circulating through the wall of the bowel. This proportionate decrease ceases when the gas pressure exceeds the animal's blood pressure, and there remains a constant residual flow of blood, however greatly the loop is distended. We have checked this result repeatedly and by close observation have determined that this residual circulation occurs not through the bowel wall, but by way of small anastomotic vessels in the mesentery and along the mesenteric border of

## POSTOPERATIVE OBSERVATIONS

A summary of the facts to be deduced from table 5 includes the following:

1. A large increase in the urea and nonprotein nitrogen content of the blood was demonstrable after operation in 18 per cent of the cases studied. A similar increase but of moderate extent was demonstrated in 35 per cent of the cases. A slight increase along similar lines was demonstrated in 11 per cent of the cases.

TABLE 5.—*General Table of Facts Observed Before Operation and Their Comparison with Similar Facts Observed After Operation*

Case	Age	Anteoperative Estimations				Postoperative Estimations			
		Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
2	41	12.6	17.3	2.5	1.0	17.1	23.8	2.5	1.2
3	27	12.6	14.1	1.9	1.0	12.6	11.7	2.0	1.0
4	..	12.6	10.9	1.7	1.0	15.1	15.0	2.0	1.0
15	..	11.0	15.8	2.1	1.7	15.1	15.5	2.2	1.0
19	41	11.0	11.7	2.5	1.1	22.1	11.7	2.5	1.2
20	..	11.0	11.7	2.5	1.0	11.7	16.1	2.5	1.2
21	33	11.0	17.3	2.0	1.1	18.2	15.0	1.5	1.1
27	63	11.0	11.7	2.5	1.1	19.6	15.0	3.0	1.2
34	32	11.0	11.7	2.7	1.7	22.5	11.7	1.1	1.0
21	..	15.0	20.1	2.0	1.0	11.0	10.9	2.0	1.2
59	35	15.1	19.1	2.5	1.0	19.6	14.1	2.5	1.0
60	..	15.1	14.1	2.5	1.0	18.2	15.5	2.5	1.0
61	25	15.1	15.8	2.0	1.0	22.1	15.5	1.5	1.1
61	42	15.1	16.7	2.0	1.2	15.8	16.5	2.5	1.0
65	31	15.1	17.9	1.9	1.0	11.0	11.7	2.0	1.0
66	26	15.1	15.0	2.0	1.2	22.1	14.1	2.5	1.2
67	47	15.1	19.0	2.0	1.1	11.0	14.1	2.5	1.0
68	48	16.8	11.7	2.5	1.1	19.6	15.0	3.5	1.0
63	47	16.8	11.1	2.0	1.0	17.8	11.7	3.1	1.0
51	..	18.2	17.6	1.8	0.9	15.1	15.2	2.1	1.0
55	28	18.2	16.7	2.6	1.0	17.0	12.5	6.5	1.2
58	19	18.2	15.3	2.3	1.0	11.0	11.1	3.3	1.1
68	15	19.6	15.0	2.5	1.1	18.2	15.0	2.5	1.0
57	32	19.6	17.6	2.5	1.0	25.2	15.1	2.5	1.2
76	61	21.0	23.6	2.5	1.1	25.8	11.7	3.0	1.0
75	..	21.0	19.0	2.2	1.1	21.0	10.9	2.2	1.2
77	25	22.1	11.1	2.5	1.0	11.0	11.3	2.0	1.1
81	..	22.1	16.7	2.3	1.0	21.1	11.0	3.0	1.0
87	21	11.7	11.7	1.1	1.1	11.6	12.5	2.1	1.2
88	40	11.7	11.7	1.1	1.1	15.8	16.7	2.5	2.1
21	..	11.0	22.6	2.5	1.1	21.0	11.7	3.5	1.2

2. In 18 per cent of the cases the difference between the preoperative and postoperative urea and nonprotein nitrogen contents of the blood was not appreciable.

3. In 18 per cent of the cases the postoperative urea and nonprotein nitrogen content of the blood was less than the preoperative content.

4. The urea and nonprotein nitrogen content of the blood retained their preoperative relative proportions and remained complementary, an increase in the one being accompanied by an increase in the other. Exceptions to this rule occurred, and in the latter cases it was usually found that taken as a whole the figures were at about the same level. The complementary character of the urea and nonprotein nitrogen was especially evident when the postoperative figures were much larger than the preoperative ones.

the intestine. Pressure within the lumen cannot exert influence on the circulation at these points. Along the antimesenteric border, however, the bowel is blanched entirely free from blood when the gas pressure equals the arterial blood pressure.

When the pressure within the lumen is decreased, a proportionate increase in the rate of blood flow through the loop results. When the pressure is entirely released, the flow is equal to, or, because of hyperemia, may even exceed, the measurement taken at the outset. After the delicate technic of the experiment is mastered, this procedure can be repeated several times on the same preparation:

The tabulated results demonstrate that the rate of blood flow through the wall of the bowel is inversely proportional to the gas pressure within the lumen, resulting in complete anemic stasis when the pressure within the bowel becomes approximately equal to the arterial blood pressure.

#### COMMENT

From a consideration of these observations we can easily understand that, even in the absence of mesenteric strangulation, circulatory stasis and necrosis may develop in the obstructed bowel from gaseous distention alone. The rate at which this process operates will depend on the nature and location of the obstruction. In cases of simple occlusion in which incarceration of the bowel does not occur, reverse peristalsis may for a time prevent overdistention. Usually, however, the complicated intestinal loops trap the gas in small pockets, and the constant gaseous formation from bacterial activity readily leads to pressure sufficient to occlude the blood supply in the manner described. It is obvious, however, that this mechanism is more rapidly fatal under conditions in which a section of the bowel is incarcerated.

#### INCARCERATION OF THE BOWEL

The strangulation of hernia and the various conditions under which the bowel may be incarcerated have always been subjects of interest to surgeons. Often at the operating table a portion of the intestinal tract is found imprisoned in a situation so odd as to occasion much conjecture concerning causative factors. Frequently, the relations are of such complexity that it seems impossible to visualize a spontaneous mechanism of the bowel which could produce the incarceration. However, in studying the behavior of gas when trapped under pressure in the bowel, we have observed a phenomenon which explains these accidents. As a result of the use of the mechanism of the gas trap, we have found that a loop of intestine may slip with ease into a pocket from which there is no escape, and into which additional loops are aspirated until strangulation occurs.

The deductions to be drawn from table 6 include the following:

An increase in the uric acid content of the blood was demonstrated after operation in 47 per cent of the cases; a decrease in the uric acid content of the blood was demonstrated after operation in 41 per cent. In 11 per cent the figures remained stationary after operation. Post-operative increases of some kind of the uric acid content of the blood occurred less often than increases in the urea and nonprotein nitrogen content of the blood.

2. The dominant fact to be deduced from this table is that the occurrence of high figures for the uric acid content of the blood is part

TABLE 6.—*General Relations Between the Anteoperative and Postoperative Uric Acid Content of the Blood and Associated Clinical Phenomena*

Case	Age	Condition	Anteoperative Estimations				Postoperative Estimations			
			Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
67	47	Chronic	15.4	30.0	3.0	1.1	14.0	34.1	2.5	1.0
28	33	Chronic	14.0	36.7	3.0	1.0	....	....	....	....
64	43	Acute	15.4	36.7	3.0	1.2	30.8	66.5	3.5	1.0
13	40	Chronic	14.0	54.6	3.0	1.7	....	....	....	....
22	59	Chronic	14.0	33.3	3.1	1.1	....	....	....	....
15	..	Chronic	14.0	31.8	3.1	1.7	15.4	45.5	2.2	1.0
8	28	Chronic	14.0	47.6	3.2	2.0	....	....	....	....
41	52	Jaundice	15.4	43.4	3.3	1.8	....	....	....	....
51	45	Acute	29.4	57.7	3.3	1.0	29.4	61.0	3.0	1.0
19	44	Chronic	14.0	....	3.5	1.1	22.4	....	3.5	1.3
56	48	Acute	16.6	....	3.5	1.1	19.6	35.0	3.5	1.0
23	22	Chronic	14.0	32.6	3.5	1.1	14.0	34.1	3.0	1.2
68	35	Chronic	19.6	35.0	3.5	1.1	18.2	35.0	2.5	1.0
76	64	Chronic	21.0	25.0	3.5	1.1	23.8	....	3.0	1.0
73	53	Chronic	21.0	43.2	4.0	2.6	....	....	....	....
17	25	Acute	12.6	45.4	4.1	2.1	....	....	....	....
49	34	Chronic	18.2	62.9	4.1	1.2	....	....	....	....
24	32	Acute	14.0	33.3	5.0	1.3	18.2	35.0	3.5	1.1
80	56	Acute	29.4	....	5.3	2.0	....	....	....	....
27	63	.....	14.0	33.3	2.5	1.1	19.6	35.0	3.0	1.2
21	..	.....	15.0	34.1	2.0	1.0	14.0	40.9	3.0	1.3
58	30	Chronic	18.2	35.2	2.2	1.0	14.0	34.1	3.5	1.1
61	25	Chronic	15.4	35.8	2.0	1.0	22.4	37.6	3.5	1.1
2	41	Acute	12.6	33.3	2.5	1.0	20.4	53.8	3.5	1.2
57	52	Acute	19.6	37.6	2.5	1.0	25.2	53.4	3.5	1.3
55	28	Chronic	18.2	36.7	2.6	1.0	63.0	122.5	6.5	1.3
88	40	Chronic	....	....	....	....	65.8	136.7	7.5	2.4
87	24	Chronic	....	....	....	....	54.6	129.5	2.4	1.2

of a general increase in the blood contents of the other nitrogenous bodies, that is, urea, nonprotein nitrogen. In this regard, clinical corroboration of the experimental work of Bollman, Mann and Magath could not be found, and association between liver destruction and high uric acid contents of the blood could not be clinically demonstrated. An important cause for this is probably the enormous compensatory capacity of the liver.

3. The postoperative increase in the uric acid content of the blood was not always associated with a postoperative nephritis (either new or an exacerbation of an anteoperative nephritis). In some of the cases in which a nephritis was present a postoperative decrease occurred instead, and in one case (no. 56) the figures remained stationary.

# THE GAS TRAP

A simple experiment demonstrates this mechanism. In a globular flask of about 500 cc. capacity a smooth hole is blown approximately 2 cm. in diameter. Through this hole a small loop of a dog's intestine is passed into the flask. The lumen of the gut is tied off a short space proximal to the flask and into this pocket a quantity of air is injected by means of a large syringe and needle. This air rushing into the lumen of the gut confined in the flask causes a sudden distention of that portion of the bowel, producing an effective valve. Neither the gas nor the intestine is now able to escape through the opening into which

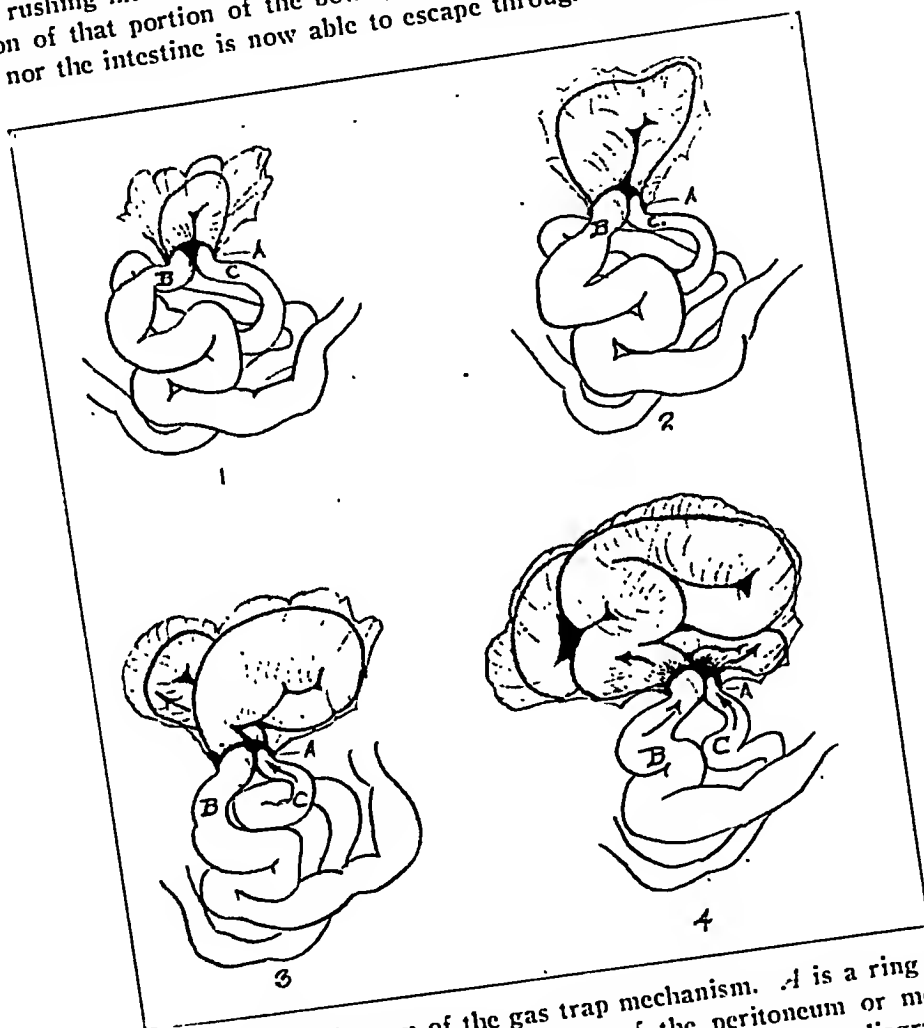


Fig. 2.—Schematic diagram of the gas trap mechanism. *A* is a ring or band which constitutes the opening into a pocket of the peritoneum or mesentery. *B* is the afferent intestinal loop and *C*, the efferent portion. In diagram 1 the process is just beginning. In diagram 2 the bowel in the pocket is over distended by gas forced in from *B* and trapped by the valvelike action of the ring. Diagrams 3 and 4 show successive steps in the inclusion and incarceration of the bowel, as traction from the pocketed and distended loop pulls more intestine into the trap, as shown by the arrows.

the flaccid bowel passed with ease. Furthermore, if another bolus of gas is forced in, causing still greater compression in the trap, several inches of bowel will be aspirated into the flask by the traction of the intestinal loops to give the compressed gas more space. This process continues till the flask is filled with distended intestinal loops.





In this connection, retroperitoneal hernia becomes a subject for interesting speculation. This condition is one in which most of the small intestine is incarcerated in a peritoneal sac arising from the fossa of Treitz, or one of the other folds of the mesentery about the duodeno-jejunal juncture. Andrews,<sup>5</sup> in discussing this condition, has maintained that the so-called duodenal hernia is a congenital anomaly in the development of the peritoneum whereby the small intestine is imprisoned beneath the mesentery of the developing colon. We are in sympathy with the view that the origin of these conditions may be embryologic. We believe, however, that the phenomenon shown by the gas trap offers an alternative mechanism in the production of these incarcerations. Andrews states that differential pressures are lacking within the abdominal cavity, and he doubts the existence of any force able to segregate the whole small intestine in a sac.

As a result of our experimental observation of the gas trap, we cannot hold to this view. An adhesive band, a hernial ring or an abnormal fold of the peritoneum may isolate a section of the intestinal lumen. Active peristalsis from above forces a bolus of gas into the pocket, and, due to its valvelike action, the gas does not escape. The process is repeated, and the gas, now under increased pressure, causes the loop to distend, exerting a traction which aspirates more intestine into the pocket till the pressures are again equalized. In this way it is conceivable that, under the proper conditions of elasticity and relaxation, many loops of intestine may be drawn into a pocket which at the outset included only a small section of the lumen.

It is evident that such a mechanism must explain the large internal hernias in which most of the small bowel slips through an artificial opening in the transverse mesocolon following gastro-enterostomy. It is not impossible that the same mechanism operates in the retroperitoneal hernia.

The length to which this process of inclusion may continue depends on the mobility of the intestinal loops and the nature of the pocket formed. In many instances a small incarceration is strangulated at once. In other cases the imprisoned mass may attain great size without strangulation.

The differentiation is a question of the pressure relations which arise. When the valvelike action is sufficient to cause venous stasis, the resulting congestion and swelling cause strangulation. Further gaseous distention by bacterial action in the strangulated loops rapidly produces gangrene.

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5. Andrews, E.: Duodenal Hernia—A Misnomer, *Surg. Gynec. Obst.* **37**: 740 (Dec.) 1923.

A summary of the facts to be deduced from the table includes:

1. An increase in the urea and nonprotein nitrogen content of the blood occurred after operation in 67 per cent of the cases studied, a decrease occurred in 1 per cent and 22 per cent remained the same.

2. An increase in the uric acid content of the blood occurred after operation in 38 per cent of the cases, a decrease occurred in 13 per cent and in 50 per cent the content remained the same.

3. The figures for the anteoperative and postoperative creatinine contents of the blood were practically identical.

TABLE 8.—*The Relationship of the Blood Examination to the Fluid Intake, Output and Daily Bile Drainage in Case 89*

Day of Illness	Fluid Intake, Cc.	Fluid Output, Cc.	Bile Drainage, Cc.	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
Anteoperative.....	.....	.....	...	15.4	33.3	2.3	1.2
Postoperative							
3.....	.....	1,100	500	38.6	63.3	3.5	1.3
4.....	500	480	480				
5.....	1,000	1,000	420				
6.....	1,000	330	100				
7.....	1,000	390	300				
8.....	1,500	540	330	19.6	49.0	2.5	1.0
9.....	1,000	510	360				
10.....	500	500	240				
11.....	1,500	500	330				
12.....	1,200	510	630				
13.....	1,200	1,100	830	15.4	40.0	2.0	1.1
14.....	1,200	1,020	600				
15.....	1,750	1,140	?				
16.....	1,000	1,100	...	14.0	....	2.5	1.0
17.....	1,200	1,050					
18.....	1,400	1,050					
19.....	1,600	1,000					
20.....	2,100	1,500					
21.....	1,200	1,000	...	14.0	33.3	2.5	1.0
22.....	1,400	1,200					
23.....	1,400	1,100					
24.....	400	1,000	...	12.6	29.3	2.5	1.2
25.....	800	1,600					
26.....	1,000	1,000					
27.....	700	900					
28.....	1,500	950	...	12.6	32.6	2.5	1.1
29.....	1,400	975					
30.....	1,500	1,000					
31.....	1,500	?					
32.....	1,500	1,100					
33.....	1,300	?					

4. The general proportional relationships of these quantitative changes repeats the deductions made from table 6.

Case 89 shows the relationship of the blood examinations to the daily total fluid intake and output and to the daily bile drainage.

CASE 89.—This was an uncomplicated case of chronic cholecystitis with cholelithiasis, for which a cholecystectomy was done with the introduction of bile drainage. Jaundice and the evidences of a nephritis were absent both before and after operation. The results of the laboratory examinations are given in table 8.

Case 89 is a good illustration of the fact that increases in the blood figures which occur after operation need not be dependent on a diminution of the fluid intake and need not be related to the total fluid intake

CASE 37.—*Periosteal sarcoma, small, round cell, of left clavicle; total excision followed by toxin treatment; patient well seventeen years later.*

J. W. H., a man, aged 34, gave as his family history that his father died of cancer of the stomach; there was no tuberculosis in the family. In January, 1908, the patient was struck on the left clavicle and almost knocked down by a plank; shortly after a local swelling appeared and grew rapidly; this was accompanied



Fig. 60 (case 141 in table 7).—Periosteal sarcoma of upper end of humerus.

by mild pain. March 23, he consulted Dr. W. L. Hunt of Bangor, Maine, who made a diagnosis of sarcoma; this was confirmed by Dr. S. W. Johnston of Belfast, Maine, who then referred the patient to Dr. Maurice H. Richardson of Boston. The latter did a total excision, May 18; the tumor occupied the middle and inner third, and the operation was most difficult. A microscopic examination was made by Dr. W. F. Whitney of the Massachusetts General Hospital, who pronounced it a small, round cell sarcoma. The patient was then referred to us for prophylactic toxin treatment. At this time there was considerable infiltration in the

whole lower cervical region, suggesting either a recurrence or incomplete removal; this gradually cleared up under the toxins and entirely disappeared at the end of two months. The injections were resumed at home and carried out under my direction by the family physician, Dr. H. L. Trulock of Dismount, Maine. Dr. Richardson believed the prognosis so grave from operation alone that he stated that if this man made a permanent recovery entire credit was to be given to the toxin treatment. We examined the patient in February, 1909, and found him in excellent health, having gained 26 pounds (11.8 Kg.) in weight. He has remained well up to the present time, seventeen years later. This case would probably now be classed as endothelioma by Ewing.

CASE 38.<sup>23</sup>—*Periosteal round cell sarcoma of lower third of femur. Recovery under toxins alone; limb saved; patient well seventeen years.*

A man, aged 58, had a negative family history. An exploratory operation was performed by Dr. G. M. Williamson, March 6, 1909, for a rapidly growing tumor of about two months' duration. The microscopic diagnosis report of Dr. Ruediger, the director of the state university, was round cell sarcoma. An immediate amputation was advised by several surgeons.

March 18, the patient was referred to Dr. William J. Mayo, who confirmed the diagnosis and refused to amputate, believing the condition to be inoperable. In writing to Dr. Williamson, the Drs. Mayo stated: "There is a question in our minds that we could accomplish anything by amputation." On Dr. Mayo's recommendation, the patient was put on a course of the mixed toxins of erysipelas and *Bacillus prodigiosus*. The injections were given by Dr. Williamson under our direction; they were continued for about four months, the dose being increased to the point of producing a marked reaction. The patient made a complete recovery; he is in excellent health, with a useful limb, over sixteen years later.

We have been unable to obtain a section of the original tumor, and the slide of the state laboratory was lost. On writing to the Mayo Clinic for further data on the case, the following report was received by Dr. Henry W. Meyerding, March 6, 1925: "The radiologist here reported some roughening of periosteum; the shaft of the bone appeared normal, and there was a shadow of soft tissue which might possibly be sarcoma. Dr. E. H. Beckman operated, March 22, 1909. He described his operation as a curettage of necrotic tissue and removal of a scale of bone. The specimen sent to the laboratory was reported 'inflammatory—possibly lues' by Dr. W. C. McCarty. This diagnosis has recently been confirmed by Dr. Broders."

As the curettings of an unhealed sinus from an exploratory operation are not infrequently negative, we believe that the clinical and roentgen-ray diagnosis supplemented by the positive microscopic diagnosis of the state laboratory, leaves little question of the correctness of the original diagnosis of periosteal round cell sarcoma. This was probably a case belonging to Ewing's endothelial myeloma group. There was no question in the minds of the Mayos that it was sarcoma.

CASE 39.—*Sarcoma of humerus; toxin treatment; apparent disappearance followed by recurrence; amputation followed by toxins; recurrence; incomplete removal of growth, followed by further toxin treatment; patient well ten years and then died of lung metastases.*

F. L., a man, aged 35, with a negative family history, was referred to us by Dr. J. M. T. Finney of Baltimore, in June, 1910. At this time he had the

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23. This patient was treated by Dr. G. M. Williamson of Grand Forks, N. D., under our direction; a full report was published in Tr. North Dakota S. M. A., 1910.



with the return circulation, causing ascites or edema of the lower extremities. Clinically, the tumor is superficial. It may be continuous with liver dulness; it is movable laterally, but is fixed above, and may suggest fluctuation. There is only slight pain or functional disturbance until the tumor has reached considerable size. Cannus reports two cases of his own which apparently belong in this category, and he refers to three others in the literature, those of Eve and Meridith<sup>4</sup> and that of Braun.<sup>5</sup> Two of these patients died within a year with recurrence.

Another Paris thesis in the same year (Lavocat<sup>6</sup>) is devoted to a clinical study of malignant tumors of the great omentum. Lavocat, however, does not make a distinction between the malignant growths which may reasonably be considered as primary in the omentum and those which simply represent secondary involvement from cancer of other structures. While the clinical study is exhaustive and interesting, the cases reported cannot be accepted in the consideration of primary sarcomas of the omentum.

The most satisfactory study of primary malignant tumors of the great omentum is that of von Stopelmoehr.<sup>7</sup> He refers to two extensive collections, those of Monnier (Prutz and Monnier<sup>8</sup>) and Losinski.<sup>9</sup> The latter's article was not available. Monnier has included some cases which I do not consider as primary sarcomas and has missed some which von Stopelmoehr has accepted in his list. In discussing the anatomic relations and development of the omentum, von Stopelmoehr would exclude: (1) growths which occur in the gastrohepatic and gastrocolic omentum, since they may arise from the liver, stomach or retroperitoneal structures, and since the tissue differs considerably from that of the great omentum; (2) growths which arise in the lesser peritoneum or bursa omentalis, since, according to Lexer, this is a favorite site for fetal inclusions and teratoid mixed tumors of the abdominal cavity, and (3) tumors which are directly adherent to the stomach or colon, which involve the walls of these organs or which necessitate resection of the bowel or stomach. Therefore it is difficult or impossible to classify accurately some of the cases which are well advanced when discovered.

Von Stopelmoehr quotes Monnier concerning primary new growths of the omentum. He classifies as cystic tumors, lymphatic and traumatic tumors, echinococcus, cysts and dermoids; and as solid tumors, lipoma, fibroma, sarcoma and myxoma. Von Stopelmoehr accepts Monnier's classification for the benign tumors, and adds to the malignant growths the rhabdomyoblastoma and hypernephroma. He discusses the proper classification of the endotheliomas, quoting Borst and Aschoff, who consider all types of endothelioma, hemangioma and lymphangioma as Sarcomas are not encapsulated, being covered only by a thin cellular layer (peritoneum). They grow rapidly, displace viscera, and may interfere

and output. In this case, increases in the blood figures occurred after operation when the fluid intake and output were at normal levels. During the second week after operation, the fluid intake and output were curtailed materially as compared with the preceding and subsequent intake and output, but during this time the figures for the urea, nonprotein nitrogen and uric acid contents of the blood receded to the preoperative levels.

This observation seems to corroborate the statement previously made that these metabolic disturbances are most probably related to the liver mechanism.

A summary of the facts to be deduced from table 9 includes the following:

1. An increase in the urea and nonprotein nitrogen content of the blood occurred after operation in 86 per cent of the cases, while in 14 per cent there was a decrease.

2. An increase in the uric acid content of the blood occurred after operation in 66 per cent of the cases, and in the remainder the figures remained stationary.

3. The creatinine content of the blood was not changed after operation.

In the cases in which jaundice appeared as a new phenomenon after operation, the postoperative increases are slight. In these cases the postoperative examinations of the blood were made almost simultaneously with the appearance of the jaundice, which probably accounts for the smaller increases after operation. It seems fair to assume from this difference that jaundice must be present for a sufficiently long period, possibly a number of days, before it can cause its maximum effects in aiding the blood retention.

Cases 30 and 28 give the detailed laboratory notes of two cases in which jaundice developed after operation. The jaundice in case 30 was mild.

CASE 30.—In the presence of an acute suppurative cholecystitis with cholelithiasis without jaundice, nephritis or other complication in a patient 44 years old, the following laboratory data were obtained before operation and after a cholecystectomy had been done. The process seemed limited to the gall-bladder. Temporary jaundice developed after operation, but nephritis and other complications did not follow. The results of the laboratory examinations are given in table 11.

CASE 28.—A cholecystectomy was performed for a chronic cholecystitis and cholelithiasis without any complicating factor; prior to operation nephritis and jaundice were not present. The postoperative course was disturbed by an obstructive jaundice. There was never any drainage of bile from the operative wound. The jaundice finally disappeared, and the patient left the hospital well. The results of the laboratory examinations are given in table 12.



differentiation is impossible. The term "pseudo-omental tumors" is applied to those which are found in the omentum, but which originate in the stomach or colon. He excludes eighteen cases which have been reported in the literature as properly not to be considered as primary tumors of the omentum. He also rules out others concerning which the reports are incomplete. I was particularly interested in one case which he excluded (McFarland's<sup>10</sup>), since I had also followed up the record. A personal communication from Dr. McFarland<sup>11</sup> makes it clear that he considers this a carcinoma, and the gross description shows that the omental involvement was undoubtedly secondary.

In the Swedish literature, von Stopelmohr was able to find only one authentic case in addition to his own. He has compiled all the reports he could find in the literature of Europe, North and South America and South Africa. He accepts forty-eight cases in addition to his own, which he classes as primary sarcoma of the omentum. It is apparent that the original reports have been studied in the consideration of each case, and that much discrimination was used in accepting the ones which come in this category. I had previously reviewed the original reports concerning six of the American cases which von Stopelmohr includes in his list: Matas,<sup>12</sup> Cobb<sup>13</sup> (two cases), Hasbrouck,<sup>14</sup> McLean<sup>15</sup> and Karsner.<sup>16</sup> Hasbrouck's specimen has been studied in Bloodgood's laboratory, and was there considered as a benign lymphogenous cyst. It probably should not be considered as a sarcoma. Matas' case<sup>12</sup> seems to be definite, the tumor being found at the first operation as a localized mass with a few secondary deposits, which were removed. There was recurrence with myxomatous masses, together with a myxomatous ascites. The patient died, and autopsy was performed. This gives a complete picture of a primary growth and recurrence of myxosarcoma. Cobb's<sup>13</sup> first case conformed to the description of a primary malignant growth of the omentum, and the diagnosis was confirmed at autopsy. Cobb remarks that of fourteen cases of malignant disease of the omentum recorded at the Massachusetts General Hospital, there are only two cases of primary sarcoma. McLean's<sup>15</sup> case was one of a localized tumor which weighed 10 pounds (4.5 Kg.), lying in the great omentum. It was classified as a myxosarcoma with small round cells. The patient was known to be alive three years after the operation. Karsner's report refers to an autopsy specimen, and undoubtedly belongs in this category.

Von Stopelmohr notes that in four cases the microscopic diagnosis was not accurate. Analyzing the occurrence of the disease with respect to age, he finds that of three patients between the ages of 5 and 19, all died; of fourteen between 20 and 34, ten died; of fifteen between 35 and 49, ten died, and in one case the outcome was unknown; of twelve between 50 and 64, eight died, and in one case the outcome was

TABLE 11.—Results of Laboratory Examination in Case 30

	Urine Bile	Stool Bile	Van den Bergh	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creat- inine
May 20 Anteoperative.....	0	+	.....	14.0	33.0	2.5	1.0
May 21 Operation							
Postoperative							
May 24 Jaundice.....	+++	Trace	1:20,000	....	....	...	...
May 25 Jaundice.....	.....	.....	1:100,000	18.2	33.2	1.5	1.1
May 30 Jaundice subsiding.	.....	.....					

TABLE 12.—Results of Laboratory Examination in Case 28

	Jaun- dice	Urine Bile	Stool Bile	Van den Bergh	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creat- inine
Anteoperative.	0	0	++++	.....	14.0	36.7	3.0	1.0
May 29, operation, cholecystectomy without bile drainage								
Postoperative								
June 2.....	+	..	..	.....	....	....	...	...
June 3.....	++	..	+++	1:50,000	....	....	...	...
June 7.....	..	..	0	.....	....	....	...	...
June 10.....	+++	++++	0	1:20,000	19.6	....	1.8	1.1
June 12.....	..	..	..	1:5,000	....	....	...	...
June 14.....	..	..	..	1:10,000	....	....	...	...
June 15.....	..	..	..	.....	12.6	31.5	2.0	1.2
June 17.....	..	..	++	.....	14.0	30.7	2.5	1.0
June 18.....	..	++++	..	1:40,000	....	....	...	...
June 19.....	..	++	++	.....	....	....	...	...
June 20.....	..	..	..	1:50,000	....	....	...	...
June 21.....	..	+	+++	.....	....	....	...	...
June 22.....	..	0	..	1:50,000	....	....	...	...
June 23.....	..	..	..	1:60,000	11.2	....	3.5	1.1
June 24.....	0	..	..	1:70,000	....	....	...	...

TABLE 13.—Results of Laboratory Examination in Case 86

	Fluid Intake, Cc.	Fluid Output, Cc.	Urea Nitro- gen	Non- protein Nitro- gen	Uric Acid	Creat- inine	Van den Bergh	Jaun- dice	Urine Bile	Stool Bile	Ne- phritis
Anteoperative	.....	.....	22.4	51.2	3.9	2.0	1:200,000	++	+	0	0
Postoperative											
Feb. 19	.....	900	....	....	...	...	.....	..	..	..	..
20	.....	1,050	....	....	...	...	.....	..	..	..	0
21	1,200	720	19.6	45.5	3.5	1.2	1:120,000	+	..	..	..
22	1,440	840	....	....	...	...	.....	..	..	..	..
23	1,440	1,350	....	....	...	...	.....	+	0	..	..
24	1,440	1,020	....	....	...	...	.....	..	..	..	..
25	840	810	....	....	...	...	.....	..	..	..	..
26	720	360	....	....	...	...	.....	..	..	..	..
27	1,200	1,200	....	....	...	...	.....	..	..	..	..
28	1,580	1,320	....	....	...	...	.....	..	..	..	..
29	1,680	750	21.0	43.3	2.0	1.1	.....	..	..	..	..
March 1	1,440	1,200	....	....	...	...	.....	..	..	..	..
2	1,350	1,080	22.4	40.0	3.0	1.1	.....	..	..	..	..
3	1,980	1,020	....	....	...	...	.....	..	..	..	..
4	2,160	1,240	....	....	...	...	.....	..	..	..	..
5	1,800	1,050	....	....	...	...	.....	..	..	..	..
6	1,440	1,200	....	....	...	...	.....	..	..	..	..
7	1,620	1,170	....	....	...	...	.....	..	..	..	..
8	1,680	1,140	....	....	...	...	.....	..	..	..	..
9	1,800	810	....	....	...	...	.....	..	..	..	..
10	2,040	840	....	....	...	...	.....	..	..	..	..
11	1,680	630	....	....	...	...	.....	..	..	..	..
12	2,160	720	....	....	...	...	.....	..	..	..	..
13	1,150	540+	16.5	36.7	3.5	1.2	1:400,000	0	0	+	..
14	2,240	810	....	....	...	...	.....	..	..	..	..

unknown; of two whose ages were not given, one died. With respect to sex, he finds: nineteen cases occurred in men, of whom fourteen died, four survived, and in one case the result was not given. Twenty-seven cases occurred in women of whom nineteen died, seven survived, and in one case the result was not given. Von Stopelmohr gives the histology of these cases in the following table.

Cystic tumors were described frequently, particularly among the circumscribed, and to a lesser extent among the diffuse, tumors; seven instances were noted in the spindle cell group, one each in the circumscribed and diffuse myxosarcomas, three circumscribed and one diffuse in the round cell group, two in the circumscribed angiosarcomas and one each in the mixed cell and lymphosarcomas. The weight of the tumors varied from 500 Gm. to 5,000 Gm. Ascites was present in twenty cases, and was noted as being bloody in eight, especially in the

*Form and Histology of Tumors*

Histology	Circumscribed			Diffuse			Total
	Dead	Living	Unknown	Dead	Living	Unknown	
Spindle cell sarcoma.....	4	3	1	1	0	0	9
Myxosarcoma .....	2	0	2	3	1	0	8
Round cell sarcoma.....	3	2	0	2	0	0	7
Angiosarcoma .....	1	1	0	5	0	0	7
Fibrosarcoma .....	3	3	0	0	0	0	6
Mixed cell sarcoma.....	0	1	0	3	0	0	4
Lymphosarcoma .....	2	0	0	1	0	0	3
Not given.....	0	0	1	3	0	0	4
Totals.....	15	10	4	18	1	0	48

vascular tumors, in the presence of torsion of the pedicle, or when repeated tapping had been necessary, eleven cases are classified as cured without recurrence or metastasis.

Some of von Stopelmohr's conclusions are interesting and pertinent. His review includes forty-eight cases of primary malignant tumors of the omentum, including the gastrocolic portion. Angiosarcoma usually occurs in people over 50 years of age, is most often diffuse, and is more frequent in women. Sarcomas may be circumscribed or diffuse. The fibrosarcoma is most favorable for treatment, as is the spindle cell sarcoma, when it is circumscribed. In seven cases, the sarcoma was in the gastrocolic omentum, in four it was pedunculated, and in three it was found in a hernial sac. These tumors are vascular, with a tendency to cystic change through necrosis. Circumscribed tumors may reach great size. The fibrosarcoma is usually the smallest. Ascites is present in about 50 per cent of the cases, most often with angiosarcoma, least often with fibrosarcoma. It often becomes blood-tinged. Metastases are most frequent with diffuse growths, especially angiosarcoma, least often

monary signs present themselves early, it is not necessary to infer that embolism is the cause. It is conceivable that emboli can reach the operative field as early as the first postoperative day.

Conclusions drawn from the foregoing comment lead us to believe that a lung abscess is in the majority of instances the result of embolism. Could this be proved by experimental investigations, a strong evidence would appear in favor of the embolic source of postoperative pulmonary complications. Such a simplification of all postoperative pulmonary complications would be desirable.

## II. PREVIOUS ATTEMPTS AT EXPERIMENTAL PRODUCTION

A review of the many varied articles on lung abscess does not disclose a single discourse in which the experimental production of the condition forms the basis for the treatise. Occasional reference, however, reveals that certain procedures have been employed with expectations of a reduplicative lesion, but in all instances the various measures used have been futile. A consideration of the pathogenesis of lung abscess exposes two possible means by which bacteria can be made to reach the desired focus: (1) through the air passages by allowing septic material to be aspirated or by direct transtracheal implantation, and (2) through the blood stream by placing infected material into the venous circulation. The activities of the previous investigators have been entirely centered on the first method of approach, and no attention has been given to the second route of invasion. Aschner<sup>90</sup> was unable to produce the lesion in dogs by means of intratracheal insufflation of pieces of tonsil and adenoid, pus from clinical cases and cultures of anaerobes.

Lambert and Miller<sup>91</sup> were likewise unsuccessful. The uniform presence of anaerobic bacteria in their lung abscess cases led them to believe that such organisms played an important bacteriologic rôle, but when these anaerobes were injected intratracheally into monkeys no lesions developed. Further evidence of the difficulties encountered in producing lung suppuration is demonstrated in a recent article by Scarff.<sup>90</sup> Various bacterial cultures were injected directly into the lung through the chest wall or by opening the chest. Preliminary injections of boiling water and the occlusion of the bronchus with foreign bodies were also carried out as supplementary measures. Failure to produce lung suppuration in any one of the fifty dogs was the result. Although the work of Kline<sup>91</sup> does not concern experimental lung abscess, it is

90. Scarff, J. E.: Pulmonary Blood Pressures: An Experimental Study. *Arch. Surg.* 12:591 (Feb.) 1926.

91. Kline, B. S.: Experimental Gangrene. *J. Infect. Dis.* 32:481 (June) 1923

with fibrosarcoma; in seven cases they were found outside of the abdomen. Fifty per cent of the cases showed adhesions. Omental tumors show a symptom-free period of from five months to two and a half years; then fatigue, loss of weight, abdominal pain, gastric disturbance and fulness of the abdomen appear as symptoms of a tumor. Pain is often caused by adhesions to other organs. In some cases one can palpate a tumor superficially in the region of the umbilicus. Occasionally it is low, and then it is difficult to distinguish from a pelvic mass. Eleven patients were apparently cured, that is, the tumors did not recur for more than one year in four cases and for eight years in one case. Patients with round cell sarcomas, fibrosarcomas and spindle cell tumors, if circumscribed or pedunculated, apparently may be cured. Ascites is not of prognostic significance unless it is bloody; then it is an unfavorable symptom.

Von Stopelmohr's article has been reviewed in considerable detail, because it is an excellent and comprehensive study of the entire subject, and is relatively inaccessible to American readers.

There are several types of tumors which are frequently mistaken for sarcoma, and some of them have been reported as such. They comprise inflammatory tumors, results of torsion and disturbed circulation, hemorrhagic infarctions, lymphogenous cysts, endotheliomas and lipomas. Inflammatory masses in the omentum are well discussed by Hertzler<sup>17</sup> as "epilpoitis plastica." They consist of fibrinoid and cellular infiltrations analogous to certain types of woody phlegmon, and are on the borderline between a reactive process and malignancy. Some instances are reported following operations for hernia, excision of portions of the omentum, torsion of the omentum without gangrene and certain inflammatory lesions in the abdomen. Pathologically, they are usually diffuse masses, rather hard, sometimes friable, with a relatively poor blood supply, and sometimes contain hemorrhagic areas. In rare cases there is necrosis with adhesions to adjacent structures. At operation such masses are sometimes mistaken for malignant growths, and are left as being inoperable. Microscopically, there is cell infiltration consisting of leukocytes in cases in the early stages, and of large round cells with fibrinous material in cases of long standing. Well preserved blood cells are often found. There may be spindle cells simulating young connective tissue. As Bloodgood<sup>2</sup> states: "Inflammatory reactions in fat such as omentum are extremely difficult to distinguish from sarcoma." In his series, which consisted of seventeen specimens of omental tumors up to 1920, seven were classed as omental cysts and ten as chronic inflammatory tumors.

I have notes furnished by Dr. Donald Miner<sup>18</sup> of Jersey City concerning a case of omental tumor. A man, aged 42, had an operation following an acute attack of abdominal pain, with tenderness and vomit-

of some significance in that gangrenous pulmonary lesions were developed by the intratracheal injections into rabbits of spirochetes, fibrin bacilli and other organisms obtained from the fluid of a gangrenous lung.

Most investigators contend that lung abscess cannot be produced in animals by intrabronchial manipulations, and deductions from the meager experimental reports convince us that this is true. In the experiments carried out in this laboratory the same results were experienced.

### III. PRESENTATION OF EXPERIMENTAL RESULTS AT PRODUCTION

The following experimental studies are based on the two major theories pertaining to the formation of postoperative lung abscess. The material has therefore been classified according to the method used in introducing the infection: (1) by way of the bronchi, and (2) by way of the blood stream. Dogs were used in all the experiments.

#### INTRABRONCHIAL INJECTION SERIES

*Technic.*—In a series of fifteen experiments, the bronchoscope was introduced in animals under ether anesthesia following the administration of morphine, one-sixth or one-fourth grain (0.01 or 0.016 Gm.). Various materials, such as freshly obtained bits of human tonsil and adenoid tissue, infected meat and peanut kernels, were then placed by means of a long grasping forceps into the larger and smaller bronchi leading to a single lobe of the lung. At the site of implantation the mucous lining of the bronchus was usually scarified in order that infection might more easily occur. In some animals the lumen of a small bronchus was literally packed with tonsil tissue. In one experiment a small jagged tooth, removed from the animal's jaw, was placed into a lower lobe bronchus. A small chicken feather and a small metallic figure four were likewise used in two other dogs respectively. A mixture of gum tragacanth and cultures of *Bacillus coli* and *Staphylococcus aureus* were also employed. One end of a small, long rubber tube was filled with the mixture; the tube was then introduced through the bronchoscope into a small bronchus and the contents forced into the smaller bronchi with an air pump. In another experiment human tonsil tissue clamped with lead filings was placed into a small bronchus. The animals were carefully watched for the development of a lesion by subsequent bronchoscopic examination and with the aid of roentgenograms.

*Results.*—The results obtained from this study (table 2) confirm the work of previous investigators in that we were unable to produce a single lung abscess. The materials introduced were usually coughed up during the first few days, although in one instance, namely, the experiment in

ing. The condition was diagnosed as appendicitis. A mass measuring 6 by 2 by 1 inches (15.24 by 5 by 2.5 cm.) was resected from the great omentum, there being a definite line of demarcation. The pathologist's report was hemorrhagic inflammation, though Dr. Miner says that he thought it was an infarct. Such masses are not uncommon. Some of them result from torsion of the omentum and may become hard and fibrous, resembling small fibromas. They may be pedunculated, and may even lose their original connection with the omentum and lie free in the peritoneum or in hernial sacs. Histologically some of these tumors are made up of spindle cells and round cells. Some of them have undoubtedly been reported as cases of sarcoma, with recovery.

Associated with this type of tumor are the hemorrhagic tumors and cysts. These have been thoroughly discussed in some of the French theses, notably, by Bichon,<sup>10</sup> Reynier,<sup>20</sup> and Brunet.<sup>21</sup> Bichon presents a good historical review of the subject, with a discussion of the anatomy of the omentum. He notes that between 1885 and 1896, only two cases of omental tumor were reported in Paris, one being a lipoma and the other a hydatid cyst. He reports a personal observation of a hemorrhagic cyst of the gastrocolic omentum, and also two autopsy observations; a case reported by Simon in 1858, of a large hemorrhagic cyst of the great omentum and another by Piecaud in 1877, of a similar cyst of the gastrocolic omentum. Reynier reports three observations of such hemorrhagic masses in the great omentum, and discusses the microscopic pathology. The tumors in his cases showed small lobules of fat, which was more or less absorbed and surrounded with infiltration of embryonic tissue, with dilatation of vessels and ecchymosis. He recognized two causal factors: inflammation in adjacent organs, and hemorrhage and infiltration secondary to torsion of the omentum with rupture of the vessels. Brunet discusses these changes in considerable detail, and presents an excellent review of the entire subject, together with a summary of the chronic inflammatory changes. Inflammatory tumors of the omentum are also discussed by Braun,<sup>5</sup> who considers as etiologic factors: previous laparotomy, especially cases in which a portion of the omentum has been resected, strangulated hernia and local inflammatory processes. He reports a case in which an omentocele had been resected. The retained stump became swollen and retracted in the region of the spleen. The clinical diagnosis was that of malignant disease of the intestine, the mass was partially resected and thought to be spindle cell sarcoma, but at autopsy it proved to be simply an inflammatory mass. Numerous instances of changes due to torsion of the omentum caused by adhesions, fixation in hernial openings, and other conditions, are recorded by Richardson,<sup>22</sup> Corner and Pinches.<sup>23</sup> Baldwin,<sup>24</sup> Scudder,<sup>25</sup> and Eitel.<sup>26</sup> Payr<sup>27</sup> obtained torsion of the omentum by the production of multilocular gas cysts by means of the injection of metallic

which the tooth was used, fourteen days elapsed before expulsion occurred. Three animals succumbed from empyema due to accidental perforation of a bronchus at the time of the initial bronchoscopy. The other animals remained well, and no lesions developed in the region of the implanted foreign body.

TABLE 2.—*Intrabronchial Injection Series*

Experiment	Description of Injection		Resultant Lesion
	Material	Location	
1 ( )	Infected meat.....	Right lower lobe bronchus	Animal died from empyema on third day due to accidental perforation of bronchus at time of last tracheotomy
2 (Y 2)	Human tonsil.....	Right lower lobe bronchus	None; foreign body expelled
3 (Y 2)	Human tonsil.....	Right lower lobe bronchus	None; foreign body expelled
4 (Y 2)	Human tonsil.....	Right upper lobe bronchus	None; foreign body expelled
5 (Y 2)	Bits of human tonsil.....	Right lower lobe bronchus	No local lesion; animal died from empyema on second day as in experiment 1
6 (Y 3)	Two peanut kernels.....	Right upper lobe bronchus	None; foreign bodies expelled
7 (Y 4)	Human tonsil and adenoid	Right lower lobe bronchus	None; foreign body expelled
8 (Y 4)	Human tonsil.....	Right lower lobe bronchus	None; animal died on first post-operative day from empyema as in experiment 1
9 (Y 7)	Bits of human tonsil.....	Right lower lobe bronchus	None; foreign body expelled
10 (Y 7)	Bits of human tonsil.....	Right lower lobe bronchus	None; foreign body expelled
11 (Y 12)	Mixture of gum tragacanth and cultures of <i>B. coli</i> and <i>Staphylococcus aureus</i>	Right lower lobe bronchus	None
12 (Y 15)	Mixture of gum tragacanth and cultures of <i>B. coli</i> and <i>Staphylococcus aureus</i>	Right lower lobe bronchus	None
13 (Y 17)	Human tonsil in gum tragacanth and lead filings	Right lower subdivision bronchus	None; foreign body expelled
	Human tonsil and lead filings	Left lower subdivision bronchus	None; foreign body expelled
	Chicken feather.....	Right lower subdivision bronchus	None; foreign body expelled
14 (Y 17)	Small jagged tooth.....	Left lower lobe bronchus	None; foreign body expelled after two weeks
	Mixture of gum tragacanth and cultures of <i>B. coli</i> and <i>Staphylococcus aureus</i>	Right lower lobe bronchus	None
15 (Y 17)	Small metallic figure 4.....	Left lower lobe bronchus	None; foreign body expelled

## PROTOCOLS

EXPERIMENT 1.—Dog Y1, weighing 8 Kg., Feb. 19, 1925, was given one-sixth grain (0.01 Gm.) morphine and  $\frac{1}{150}$  grain atropine. Under ether anesthesia the bronchoscope was introduced into the right primary bronchus and then into the bronchus leading to the lower lobe. A long wire hook was introduced and the wall of the bronchus was scarified. A small bit of cooked meat, which had been rubbed on the floor, was then introduced with a hook forceps and pushed through the wall of the bronchus presumably into the lung tissue itself.

February 21, the dog appeared ill and the respiratory rate was increased.



magnesium which formed hydrogen, and also by the introduction of paraffin. He notes that the veins are longer; hence, when twisted they become kinked and tortuous, while the arteries form a solid cord about which the omentum becomes twisted. This group of lesions and also the succeeding lymphogenous cysts and tumors undoubtedly result from disturbances in the omental circulation. An extensive examination of the textbooks on anatomy fails to disclose a satisfactory detailed account of the blood or lymph supply and drainage of the great omentum. The arterial blood supply comes principally from the right and left gastro-epiploic branches of the celiac axis, which descend in the anterior fold of the omentum. It is not clear whether these descending branches are reflected at the lower border of the omentum and extend as ascending vessels in the posterior fold; whether they develop penetrating branches which extend to the posterior layer of the omentum, or whether there are descending branches from the colica media which supply the posterior layer. In any case, obstruction of the vessels near the colic attachment will result in the infarction and fibrosis of the dependent portion of the omentum. In the first event, ligation of vessels near the periphery will result in disturbed circulation in the posterior layer of the omentum with infarction, etc. Ligation and resection of portions of the omentum always result in circulatory disturbances of the entire structure, and present the possibility of more or less serious lesions of the type already described. Freeman<sup>28</sup> discusses this subject, and mentions as possible consequences of omental resection: adhesions of the omental stump, changes in that structure, gastric or duodenal hemorrhage, and fecal necroses in the liver. The latter results are explained as due to emboli from thrombosed omental veins, since the venous return is through the portal circulation.

It is well known that both layers of the omentum contain a rich network of lymphatic vessels, and it is assumed that these follow the arterial system. Disturbances in the lymph circulation occur frequently from torsion, ligation, resection or low-grade inflammatory reaction, particularly in the relatively dependent portions of the omentum. This results in the development of lymphogenous cysts, which may be single and of large size, but are more often multilocular and multiple. Marked development of fibrous and lymphatic tissue in addition to the cystic portions may make the microscopic picture confusing. Dr. J. C. Bloodgood of Baltimore<sup>2</sup> classifies seven of his eighteen specimens in the category of omental cysts. Excellent discussions of these lesions in typical cases occurring in America are found in the reports by Outerbridge,<sup>29</sup> Kenny and Mason,<sup>30</sup> Austin<sup>31</sup> and Doud.<sup>3</sup> Some of these cysts may reach considerable size, with extensive tissue changes in the surrounding omentum. The histologic picture is often confusing, so it is not surprising that some of these cases have been reported as malig-

February 22, the dog was found dead in his cage. Necropsy revealed a bilateral empyema. A small perforation led from the bronchus into the pleural cavity. The pleural infection evidently resulted from perforation into the pleural cavity at the time of instrumentation.

EXPERIMENT 2.—Dog Y2, weighing 5.7 Kg., March 5, 1925, was given one-sixth grain (0.01 Gm.) of morphine and  $\frac{1}{150}$  grain of atropine. Under ether anesthesia a 9 mm. bronchoscope was introduced into the right lower lobe bronchus. The wall of the bronchus was scarified with a long wire hook and a section of human tonsil was implanted next to the injured bronchial wall.

March 19, the dog was submitted to bronchoscopic examination under ether anesthesia. The foreign body introduced two weeks previously could not be found and no signs of inflammation were present. The same area on the bronchial wall was scarified.

April 2, a preliminary hypodermic injection of one-sixth grain of morphine and  $\frac{1}{100}$  grain of atropine was given followed by ether anesthesia. Bronchoscopic examination revealed a normal bronchus.

EXPERIMENT 3.—Dog Y2, April 2, 1925, was given one-sixth grain of morphine and  $\frac{1}{100}$  grain of atropine. Under ether anesthesia the bronchoscope was introduced into the right lower lobe bronchus. The bronchial wall was again scarified until bleeding occurred and a small piece of freshly obtained human tonsil containing caseous cryptic material was placed next to the injured bronchial wall. Cultures for the predominating organisms were taken from the tonsil.

April 6, bronchoscopic examination revealed no evidence of inflammation. The foreign body could not be found. The bacteria found in the culture consisted of short chain streptococci, staphylococci and gram-negative bacilli.

EXPERIMENT 4.—Dog Y2, April 16, 1925, was given one-sixth grain of morphine and  $\frac{1}{100}$  grain of atropine. The bronchoscope was introduced with the dog under ether anesthesia. The right upper bronchus was scarified until bleeding occurred. A large piece of human tonsil sufficient in size to occlude the bronchus was introduced.

April 30, bronchoscopic examination revealed the bronchial lumen to be patent. There were no signs of inflammation.

EXPERIMENT 5.—Dog Y2, April 30, 1925, was given one-sixth grain of morphine and  $\frac{1}{100}$  grain of atropine. Under ether anesthesia, the bronchoscope was introduced and finely chopped bits of human tonsil tissue were placed into the right lower bronchus blocking it entirely.

May 1, the dog appeared sick and would not eat.

May 2, the dog was found dead in his cage. Necropsy showed a bilateral empyema. A small perforation led from a lower lobe bronchus into the pleural cavity. The pleural infection was attributed to perforation of the bronchoscope into the pleural cavity.

EXPERIMENT 6.—Dog Y3, weighing 9.4 Kg., May 28, 1925, was given one-sixth grain of morphine and  $\frac{1}{100}$  grain of atropine. Under ether anesthesia the bronchoscope was introduced into the right upper main stem bronchus and two pieces of peanut, constituting approximately one-half the kernel, were inserted into the bronchial lumen.

June 8, bronchoscopic examination showed no inflammation. The foreign bodies were missing.

June 17, the dog was killed in a fight. There was no evidence of an infectious process.

nant endotheliomas or sarcomas. At least one, that reported by Hasbrouck,<sup>14</sup> is undoubtedly a lymphogenous cyst, but is classed by von Stopelmohr as a cured sarcoma. On the other hand, it is not impossible that a lymphogenous cyst may occasionally be associated with some type of lymphosarcoma.

A number of new growths in the omentum have been described and reported as endotheliomas, and the term has given rise to some confusion. Ewing<sup>33</sup> and MacCallum<sup>34</sup> accept a definite group of new growths under this classification. They recognize a distinct type of endothelial tissue occurring in the serous membranes, the peritoneum, the pleura and the meninges, and in the lymph and blood vessels. They believe that this tissue gives rise to a definite type of malignant new growths which present some of the characteristics of sarcoma and in other regions may resemble carcinoma. Since the omentum is richly supplied with these tissues, one would expect to find this type of tumor arising in that structure. Because of the confusing microscopic picture, some of these have undoubtedly been reported as primary cancer of the omentum, and it is not improbable that some cases of secondary cancer without a demonstrable primary source have been reported as endothelioma of the omentum. Other pathologists do not accept this group of tumors as a distinct entity. McFarland<sup>11</sup> does not believe that endothelial cells are capable of tumor growth and does not recognize this type of new growths. It is evident that the term endothelioma has been loosely applied, and careful study has resulted in a restriction of the group. The question seems to depend on the actual embryologic origin of the endothelial cells of the blood vessels and lymphatics. If of mesodermal origin, they give rise to some kind of sarcoma; if they are to be considered as an independent type of cells, they give rise to a distinct type of malignant growth intermediate between the sarcoma and carcinoma. Two questions are involved in a consideration of the malignant growths supposed to originate in the serous membranes, particularly in the peritoneum, pleura and meninges. There is considerable doubt, first, whether these tumors actually arise from the endothelial cells or from the underlying supporting tissue; and second, whether the endothelium is to be considered as developing from the connective tissues or as an independent layer. Until it is possible to settle this somewhat academic question, it would seem simpler to consider this group of tumors as a variety of sarcoma, and avoid all confusion with carcinoma, which must always be a secondary growth in the omentum. The microscopic picture is often confusing, and differential diagnosis by this means alone is not always possible. The clinical history, preoperative and postoperative, and the gross anatomic relations of the tumor must always be taken into consideration. In some advanced cases absolute differentiation is out of the question.

EXPERIMENT 7.—Dog Y4, weighing 14.6 Kg., May 28, 1925, was given one-fourth grain of morphine and  $\frac{1}{160}$  grain of atropine. Under ether anesthesia the bronchoscope was introduced into the right lower lobe bronchus and the lumen was entirely filled with human tonsil and adenoid tissue.

June 2, bronchoscopic examination revealed no inflammation of the bronchial mucous membrane. The tonsil tissue had been expelled.

EXPERIMENT 8.—Dog Y4, July 2, 1925, was placed under ether anesthesia and the bronchoscope introduced into the right lower lobe bronchus. An entire tonsil was cut into small pieces and inserted into the bronchial lumen.

July 3, the dog was found dead in his cage. Immediately after the introduction of the instrument the dog developed respiratory distress and cyanosis which grew progressively worse until death. At necropsy a perforation was found in the lung leading to a right lower lobe bronchus. The tonsil was found remaining in the bronchial lumen, but there was no evidence of inflammation. The cause of death was attributed to a pneumothorax.

EXPERIMENT 9.—Dog Y7, weighing 9.4 Kg., July 25, 1925, was given one-sixth grain of morphine and  $\frac{1}{150}$  grain of atropine. Under ether anesthesia the bronchoscope was introduced and three bits of human tonsil tissue were placed into the right lower lobe bronchus.

July 28, bronchoscopic examination revealed an absence of the tonsil tissue and no inflammatory change was visible.

EXPERIMENT 10.—Dog Y7, Aug. 7, 1925, was given one-sixth grain of morphine and  $\frac{1}{150}$  grain of atropine. Under ether anesthesia the bronchoscope was introduced and the right lower lobe bronchus filled with human tonsil tissue.

August 27, the dog was found dead in the kennels. Death was due to trauma received in a fight. The right lower bronchus gave evidence of a slight purulent inflammation also present throughout the bronchial tree. There were a few small peribronchial patches of infiltration throughout. The animal probably had distemper.

EXPERIMENT 11.—Dog Y12, weighing 10.5 Kg., Oct. 2, 1925, was given one-fourth grain of morphine. Under ether anesthesia, the bronchoscope was introduced and a mixture of gum tragacanth, *Bacillus coli* and *Staphylococcus aureus* forced through a rubber tube into the terminal bronchi of the right lower lobe by means of an air pump. The compressed chest was released at the same time so as to create a forceful inspiration.

October 5, roentgenograms of the chest showed no evidence of lung involvement.

October 8, roentgenograms of the chest revealed no altered appearance of the lungs.

October 14, roentgenograms revealed clear lung fields. Bronchoscopic examination showed no evidence of bronchial inflammation. There seemed to be an odor of *Bacillus coli* to the breath.

EXPERIMENT 12.—Dog Y15, weighing 6.4 Kg., Oct. 3, 1925, was given one-sixth grain of morphine. Under ether anesthesia the bronchoscope was introduced and a mixture of gum tragacanth, *Bacillus coli* and *Staphylococcus aureus* forced through a rubber tube into the terminal bronchi of the right lower lobe by means of an air pump. The compressed chest was released at the same time so as to create a forceful inspiration.

October 8, roentgenograms of the chest showed the lung fields to be clear.

October 14, roentgenograms of the chest revealed no change in density of the right lower lobe. Bronchoscopic examination showed no evidence of inflammation in the bronchi although here again the odor of *Bacillus coli* was detected.

Lipomas are described in the omentum, and are usually benign tumors. There is, however, an interesting relationship between these growths and a malignant type of fibromyxomatous growths, which has been discussed recently in connection with malignant lipomas of the thigh by Kellogg Speed.<sup>35</sup> This relationship may explain some of the myxomatous tumors of the omentum.

#### CONCLUSIONS

The great omentum may be the seat of a number of pathologic changes resulting in the development of tumor masses which suggest primary malignant tumors. It is often involved secondarily in malignant disease, cancer of the abdominal viscera, but such tumors are never primary in the great omentum. Concerning primary malignant disease, sarcoma of the omentum, nearly fifty cases have been carefully reported and reviewed which must be accepted in this category (von Stopelmohr<sup>7</sup>). I have studied the original reports of ten of these cases besides my own, which I believe to be definitely primary sarcoma originating in the great omentum. The latter cases were all fatal, either at the time of the original observation or subsequently from recurrence.

In order to classify a given case as a primary sarcoma of the omentum, two qualifications must be met: 1. The growth must have originated within the omentum. This is clearly demonstrable in certain cases discovered early at exploratory laparotomy in which the growth is found entirely within the serous layers of the omentum, and does not involve any of the adjacent organs. In cases in which the growth has become extensive or has developed metastases when first discovered, it may be impossible to prove that one is dealing with a primary tumor of the omentum. 2. The growth must be proved malignant. There are two criteria for determining this point: (a) microscopic examination and (b) clinical course. The microscopic picture is usually definite, and the diagnosis is readily made by any competent pathologist. The occurrence of sarcoma is so rare, however, that one hesitates to make the diagnosis on the basis of the microscopic picture alone. In many cases the histology is so confusing that microscopic differentiation is not possible. The usual clinical picture of sarcoma is recurrence or extension, in spite of early and relatively wide resection. In the case of a localized tumor which has been removed, one would hesitate to accept the diagnosis of sarcoma unless the microscopic picture was beyond question, or unless there was a history of recurrence. On the other hand, in the case of a localized tumor removed and recognized microscopically as sarcoma, with subsequent recurrence, one is forced to diagnose primary sarcoma of the omentum. These are the three absolute requirements: localized tumor located within the omentum without attachment to other structures; histologically, a sarcoma; a

EXPERIMENT 13.—Dog Y17, weighing 6.7 Kg., Sept. 21, 1925, was given one-sixth grain of morphine. Under ether anesthesia the bronchoscope was introduced and a piece of human tonsil rolled in gum tragacanth and fastened with lead filings was placed into a right lower subdivision bronchus. A piece of human tonsil clamped with lead was placed into a left lower subdivision bronchus and a small chicken feather was also placed into another one of the right lower bronchi.

September 22, a roentgenogram of the chest showed the one foreign body still present in the right lower lobe. The one on the left had disappeared. There was no evidence of any pathologic change.

September 26, a roentgenogram of the chest revealed the absence of both foreign bodies.

October 2, bronchoscopic examination revealed no evidence of inflammation. The foreign bodies had disappeared.

EXPERIMENT 14.—Dog Y17, Oct. 2, 1925, was given one-sixth grain of morphine. Under ether anesthesia, the bronchoscope was introduced and a jagged tooth of the animal was placed into the left lower lobe bronchus. A mixture of gum tragacanth, *Bacillus coli* and *Staphylococcus aureus* was also forced into the terminal bronchi of the right lower lobe in the same manner as in experiment 11.

October 5, roentgenograms of the chest revealed a faint shadow in the region of the implanted tooth, probably the foreign body itself. No evidence of a pathologic change was discernible.

October 8, roentgenograms of the chest revealed clear pulmonary areas.

October 14, roentgenograms of the chest showed no change from the preceding plates. Bronchoscopic examination revealed no evidence of inflammation in the bronchi but here again the odor of *Bacillus coli* was detected. The tooth was still present in the left lower lobe bronchus but no pus or redness of the bronchus was visible.

October 23, bronchoscopic examination showed the tooth to be absent. There was again no inflammation present.

EXPERIMENT 15.—Dog Y17, Oct. 23, 1925, was given one-sixth grain of morphine. Under ether anesthesia the bronchoscope was introduced and a metallic figure 4 was inserted into the same left lower lobe bronchus that the tooth had occupied.

October 29, roentgenograms of the chest revealed the foreign body still present in the left lower lobe. No infiltration could be seen about the foreign body.

November 15, the dog died of distemper. Examination of the left lung failed to locate the foreign body. The bronchus that contained the metallic figure 4 was of normal size. The entire bronchial tree showed the diffuse characteristic appearance of distemper.

#### INTRAVENOUS INJECTION SERIES (TABLE 3)

*Technic.*—Following and in conjunction with the discouraging results experienced with the intrabronchial methods, the idea was conceived of introducing into the large veins infected materials, which would be transported to the right side of the heart by way of the venous circulation and thence to the lung by way of the pulmonary artery. The ease with which foreign bodies can be placed within the jugular vein because of its size and accessibility and the absolute certainty of subsequent transmission to the right side of the heart led us to choose this vessel as the most suitable receptacle for such materials.

history of recurrence and extension or metastases. Cases meeting these criteria must be accepted in this group. No matter how typical the histologic picture, the absence of recurrence or metastasis will throw some doubt on a diagnosis of sarcoma.

It would be instructive to apply these criteria to the cases reported in the literature and commonly accepted in this classification. This is not possible, since many of the original reports are not available. One should, however, find three groups. 1. Positive cases: those which meet all of the necessary conditions, definitely primary in the omentum, definitely sarcoma microscopically and recurrent as sarcoma. 2. Presumptive cases: those which include advanced cases in which there is some doubt concerning the original focus of disease with extension or metastasis to other structures. Many of these undoubtedly were primary in the omentum, and in reviewing them, I am dependent on the impression of the original observer. In this group should also be included some cases in which the tumor is definitely primary in the omentum and grossly resembles a malignant growth, but either the histology is not definitely that of sarcoma, or the clinical course is incompatible with such a diagnosis. 3. Other cases are still more doubtful and should be excluded.

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Recurrence within a year was also localized within the omentum in such a manner that the surgeon found an apparently operable tumor which did not show gross evidence of extension or secondary growth. Finally there was recurrence with extensive growths throughout the abdomen at least, as proved by autopsy. The histologic pictures presented in slides made from the original growth, the recurrence and the autopsy, were similar, and confirmed the original provisional diagnosis of primary sarcoma of the great omentum.

#### REVIEW OF THE LITERATURE

The literature concerning this subject is somewhat confused in two respects: 1. It includes many cases of malignant growths which, while involving the great omentum, are not primary in that structure. 2. Many of the reports concern inflammatory masses, various types of infarction and lymphogenous cysts, any of which may closely resemble sarcoma microscopically.

The first comprehensive review of the subject is a thesis by Camus.<sup>3</sup> He discusses the anatomy and structure of the omentum, and defines what may properly be considered as a primary tumor of the omentum. He follows the teaching of Trousseau and of Eve, whom he quotes to the effect that primary cancer of the omentum does not exist, and that all cancers of the omentum are metastases or extensions of cancer in other structures. He limits tumors of the omentum to the following types: endothelioma, lymphoma, lipoma, fibroma, sarcoma (embryonic fibroma) and angioma (no cases reported). Endotheliomas originate in the surface endothelium (peritoneum) or lymphatics as white masses in the omentum. The condition may not be clearly primary in the omentum, since similar growths may be found throughout the peritoneum or even in the pleura. He refers to the autopsy reports of two cases; those of Schulze, 1876, and Lancereux, 1878, in which, however, it is not certain that the sarcomas were primary in the omentum or even in the peritoneum. He describes the lymphoma, lipoma and fibroma as benign masses which are often pedunculated. Thus they may lose their original connection with the omentum and be found as isolated tumors lying free in hernial sacs or in the peritoneal cavity. He refers to illustrative cases in the literature. Concerning sarcoma of the omentum, the author says that it is a rare tumor which grows rapidly and may reach large size. It is variable in consistency, has an alveolar structure and contains areas of colloid degeneration or pseudocystic formation. There may also be hemorrhages of the tissues, due to the rupture of vessels which are often much dilated, particularly about the periphery of the tumor. This results in the formation of hemorrhagic cysts. Sarcomas are not encapsulated, being covered only by a thin cellular layer (peritoneum). They grow rapidly, displace viscera, and may interfere



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appearance of a man of splendid physique; he was 6 feet tall and weighed 180 pounds (81.6 Kg.). Early in January, 1910, he had fallen and received a spiral fracture of the left humerus at about the junction of the middle and upper thirds. He was treated at the Hudson Street Hospital, and then returned to Baltimore, where he was treated by Dr. W. A. Fisher. A roentgenogram taken at this time



Fig. 61 (case 141 in table 7).—Three months later than figure 60.

showed a spiral fracture without any trace of a new growth. Three weeks later, he felt severe pain at the site of the fracture. Another roentgenogram was taken which showed that in the meantime a well marked tumor had developed, apparently a sarcoma, involving both the central portion and the periosteum. The growth increased rapidly in size, and was accompanied by severe and constant pain. An exploratory operation was performed by Dr. Finney in June, revealing a large sarcomatous growth that involved both the central and the periosteal

portions: the humerus and extended from about the junction of the middle and upper third nearly to the head of the bone; the bone was completely destroyed; a pathologic fracture had occurred, and there was a flail joint. The central portion of the tumor was curetted; in Dr. Finney's opinion, amputation offered no hope of a cure. June 15, the patient came to us and was immediately put on the mixed toxins; these were continued in small doses systemically in the pectoral region and a few in the arm.

The specimen was examined microscopically by Dr. James Ewing and pronounced a spindle cell osteogenic sarcoma; this diagnosis was confirmed by Dr. Joseph C. Bloodgood. There were no giant cells.

Under the toxins the tumor slowly and steadily decreased in size; there was immediate cessation of the pain which had been constant from the first appearance of the tumor; the shell of bone about the tumor, which had undergone spontaneous fracture, gradually became harder with the formation of new bone, and within a few weeks complete union had occurred; the large cavity gradually filled up with granulations. Several curettements showed the material to be sarcoma of the same type as the original tumor. Another roentgen-ray examination in the latter part of 1910 showed that the new growth had apparently entirely disappeared and there was firm union of the arm. The patient's general condition was excellent.

In November the granulations began to increase again in size and in spite of curettage, quickly recurred. A roentgenogram taken in December showed a small shadow starting in the periosteum, in the axillary region. In the early part of January, we performed a shoulder joint amputation. The patient remained well for about one year, and then developed a large, recurrent tumor, the size of two fists, in the pectoral region. We did an incomplete removal and put him on a prolonged course of toxin treatment. He remained in apparently good condition until April, 1912, when he complained of pain, and a mass below the clavicle at the top of our last incision. He consulted Dr. W. A. Fisher of Baltimore, who found a mass about 3 cm. in diameter and very sensitive. As it was impossible for the patient to return to New York at that time, he was sent to a local hospital, where Dr. Fisher, believing the present trouble to be a recurrence, removed the shoulder girdle; it proved, however, to be a large neuroma. The patient was more comfortable after the operation and gained steadily in weight and strength; in October, 1913, he weighed 212 pounds (96.1 Kg.), and was the picture of health. He remained well until 1920, when lung metastases developed; he died shortly after.

*CASE 40.—Large, osteogenic sarcoma of humerus, treated with toxins and radium; complete disappearance of tumor; patient well two years later.*

E. M., a man, aged 47, was referred to us by Drs. William C. Sheehan and John B. Deaver of Philadelphia, July 24, 1924. About a year and a half before the patient had tripped over a low fence and fractured the left humerus at the upper third. One year later a tumor developed at the site of the injury. Physical examination at the time of our first observation showed the left shoulder markedly swollen on the outer and anterior aspect, the swelling occupying the whole region of the deltoid, and extending up to the tip of the clavicle; it was soft in consistency, semifluctuating, and extended out to the pectoral muscle. The measurement over the axilla and tip of the clavicle was 21 inches (53.3 cm.), while the circumference at the highest point of the axilla was 15 inches (37.5 cm.). Motion at the shoulder was considerably limited; he could raise his left hand as high as his chin but not to the top of his head; abduction was about 45 degrees; the skin was normal in appearance; the veins were not dilated.

# OBSERVATIONS ON THE NATURAL HISTORY OF RENAL INFECTIONS\*

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The subject of infections of the kidney may be regarded perhaps as a thoroughly explored field, and yet I suspect that a great majority of capable physicians are still unfamiliar with important facts in this field and are likely to regard various stages in the same process as different disease entities. It does not seem improper, therefore, to discuss the subject further in an attempt to determine whether broad generalizations in regard to the origin and course can be deduced from the knowledge now at hand.

I am intentionally excluding from consideration certain large groups of cases. Those which are definitely secondary, and which are regarded as a natural consequence of other lesions of the urinary tract are not considered. In this group belong the infections of the kidney secondary to other diseases of the kidney, such as stone and tumor, and infections clearly consequent on gross organic obstruction of the lower urinary tract. In the latter group belong the infections caused by urethral obstruction, whether from stricture or the prostate. I wish also to exclude tuberculosis, since in important particulars it departs in behavior from other types of infection and seems sufficiently important to merit separate consideration.

One is tempted to speak of the group now under consideration as "primary infections of the kidney," but perhaps this phrase is misleading, since it might influence opinion as to the relation of such infection to infections in other portions of the body. The group should be held to include, however, the infections of the kidney which occur in organs assumed to be normal and in which there is no obvious cause influencing the development of infection. To this extent they may properly be spoken of as "primary." One may classify the group under consideration on the basis of either the bacteriologic or the pathologic observations. The latter grouping seems to me most enlightening, particularly when one is concerned with the clinical manifestations and is interested in the natural history of the process. From the point of view of the lesions, these infections may be classified grossly into two types: (1) the cortical type and (2) the pyelitic type. It should be understood that the lesions are not strictly exclusive, and that they grade more or less into each other, but both from pathologic and clinical points of view the division is satisfactory and represents groups which can be readily separated by the clinician.

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by the experience in my case that the distention did not disappear as soon as the abscess evacuated into the bowel, but about a week later, that is, as soon as the paraproctitis and pelvic inflammation subsided.

A review of the recorded histories and the course in this case show that there is a certain sameness in the symptomatology which ought to make us think, in circumstances in which a pelvic condition is likely, of a retroperitoneal abscess. All the patients had fever and a moderately high leukocyte count, indicating the presence of pus somewhere. The symptoms were all referred to the abdomen and there were no symptoms in any other part of the body; this limited the pathologic condition to a lesion in or near the abdomen.

All the patients had abdominal distention, pain and general tenderness, but no rigidity. The distention was always marked and could not be relieved by any of the known measures, and it was present even in cases like mine in which there were frequent bowel movements. Most of the patients suffered from tenesmus and some had vomiting. These symptoms were so constantly grouped together that we must consider them evidences of pelvic infection.

The associated symptoms and the history are of great importance in the diagnosis. In seven of the twelve cases (58 per cent) there was a history of an injury at the pelvis or about the hips. In these cases there very likely was a hematoma, which subsequently became infected. A history of an injury should, therefore, lead us to suspect the possibility of an abscess. In three cases there was a general infection in the course of which there was a localization of symptoms in the pelvis due evidently to a metastasis. The tenesmus which was of frequent occurrence indicates the presence of a proctitis or pararectal irritation, and it also suggests the possibility of a pelvic infection. In one or two cases there was a flexion of the thigh which immediately makes one think of a collection of fluid in the iliac fossa and possibly lower down in the pelvis. In one case in which an operation for appendicitis was performed a pelvic abscess due to infected and broken down retroperitoneal glands was found.

Reference to the table shows that a pelvic abscess has been seen at all ages, from 3 to 64 years, but at least half the patients were in the third or fourth decades. In five cases a fluctuating mass ultimately appeared in the groin; this simplified the problem of where to operate. The acute cases tend to evacuate themselves into the rectum, bladder or peritoneum. The most favorable location is into the rectum. There were three cases (25 per cent) of spontaneous emptying of the abscess into the rectum. The most serious cases are those in which there is a general infection. In this series of twelve cases there were three with a general infection and suppuration; all these patients died from exhaus-

## TYPES OF INFECTION

*Cortical Type.*—This type of infection forms a well defined disease entity. In the overwhelming majority of cases, it is produced by one of the pus-producing cocci, and *Staphylococcus aureus* or *Staphylococcus albus* will be found in large numbers. In many cases it can be shown clearly to be secondary to some focus of cutaneous suppuration or well defined infection in some other portion of the body; thus, the boil, the carbuncle, osteomyelitis and acute coccus infections of the upper respiratory tract or of the middle ear are commonly found to be related in point of time, and there is every reason to believe that the relation is direct. The medical profession in general is most familiar with the lesion in its severe form. This is the condition to which Brewer called attention in this country many years ago, referring to it as the "carbuncle of the kidney," and is the same lesion later discussed by Keyes under the name of "acute focal necrosis." This is the most spectacular manifestation of the lesion, but I strongly suspect that it is by no means the most common. If one is interested in this group of cases and is therefore looking for them, one will often see patients with acute peripheral suppuration, who at some time during or immediately after such infection develop pain referable to the region of the kidney, definite costovertebral tenderness and fever. If careful examination is made of the urine during the first few days after the occurrence of these symptoms, cocci identical with those found in the peripheral infections may be obtained. It is ordinarily believed, and I think with justification, that in these cases the infecting organism occurs in the urine chiefly during the early days, then commonly disappears and cannot be found again. Experience shows that these patients generally do not develop the more severe suppurative lesions of the kidney, but that after a longer or shorter period, varying generally between ten days and three weeks, the process subsides and the patient recovers completely. In this way, I think, are to be explained a good many of the scars so commonly seen at autopsy on the surface of otherwise healthy kidneys and which clearly are the signs of some infection which never became acute.

My own experience has led me to believe that this type of coccus infection constitutes a large majority of the cases, and that the opinion held some years ago that in most of these cases severe destruction of the kidney occurred which was likely to require radical operation, is probably wrong. With enlarging experience, I have found that the acute destructive type seems to constitute only a minority of the cases, and I believe that these lesions when not too extensive show a great tendency to spontaneous recovery.

There is, however, one manifestation of this type of infection to which attention should be called, and that is the probability of the

tion. There was another death of a man who had had symptoms for four weeks. The abscess ruptured into the rectum; suppuration continued and the patient died of exhaustion. In one case treatment was refused and the result is not known. In seven cases there was a complete cure. In five of these seven there was a definite injury and in one of the remaining two cases the course is unknown. Thus the most favorable type of case is the acute pelvic abscess following an injury.

It is worthy of comment at this point that the incidence of pelvic infection in pelvic fractures is exceedingly small. The case I am reporting is the only one I have seen among many dozens of cases of injury

*Analysis of Twelve Cases of Pelvic Abscess in the Male*

Case	Author	Age	Cause	Duration	Operation	Tumor	Spontaneous Rupture	Result
1	Bowditch	25	Injury	4 weeks	No	Abscess in left groin	Into rectum	Death
2	Burchard	40	General infection	10 days	No	.....	Into rectum	Death
3	Burchard	32	General infection	.....	No	.....	Into thigh	Death
4	Burchard	17	Injury	1 month	No	.....	Into rectum	Cure
5	Burchard	Adult	.....	2 years	Treatment refused	.....	.....	?
6	Burchard	28	Injury	2½ years	Yes	.....	.....	Cure
7	Rodman	Young boy	Injury	3 weeks	Yes	Abscess in left groin	.....	Cure
8	Thomas	50	Unknown	Several years	Yes	Mass in left iliac fossa	.....	Cure
9	Speese	8	Injury	4 days	Yes	Abscess in left groin	.....	Cure
10	Nielson	64	General infection	.....	Yes	Mass in left groin	.....	Death
11	Rosenblum and Bettman	3	?	.....	Yes	.....	Retroperitoneal drainage	Cure
12	Kleinberg	32	Injury	6 days	No	.....	Into rectum	Cure

to the pelvic bones. Many of the industrial surgeons I have spoken to have not seen any case of pelvic abscess. So that even if we assume that some instances of pelvic infection have been overlooked, its occurrence in fractures of the pelvis is undoubtedly infrequent.

#### CONCLUSION

The conclusion we drew from a study of the symptomatology and etiology as described here is that when abdominal pain, persistent and marked distention and tenderness with fever and a leukocytosis but no localized abdominal rigidity occur after an injury of the abdomen, back, pelvis or hips, or in the course of a general infection, and there are no distinguishing symptoms or signs of a very definite lesion, these evidences must be considered as being due to an accumulation of pus in the pelvis.

formation of perinephritic abscess. A study of the literature of perinephritic abscess is rather confusing, since in most of the writings on the subject there is a tendency to consider all abscesses in the perirenal space which are believed to be of renal origin. This classification seems misleading to me, since it brings into the group a large number of instances in which the perinephritic abscess is simply an expression of some outstanding and severe lesion of the kidney, such as renal calculus or tuberculosis. In these cases it is better to connect them with the primary cause and to regard them as complications caused by calculi or tuberculosis, since their management is clearly dependent on the underlying cause. If one excludes from these classifications all cases in which there are massive lesions of the kidney and all cases of abscesses in the perinephritic space which bear no relation to the kidney, such as those of bony origin, there remains an interesting and important group for which Richardson, ten years ago, suggested the title of "primary."<sup>1</sup> At that time he collected a series of fifty-nine cases from the records of the Massachusetts General Hospital. He separated from this series two groups in one of which the lesion was due to a "direct extension from a neighboring organ or structure outside the renal fascia." In this group he found five cases. He then separated a group of twenty cases with "antecedent or predominant lesions of the kidney or urinary tract." There remained a group of thirty-four cases, which he classified as "primary." In many of these he was able to show the co-existence of suppuration elsewhere, though in many cases the imperfections of the records prevented accurate deduction. Since that time there has been increasing evidence in favor of the view that this type of perinephritic abscess is probably always associated with peripheral infection and is closely related to the group of cases described in which there is evidence of cortical suppuration in the kidney, and in which recovery is often spontaneous.

The clinic with which I am associated is able to add to his observations, twelve cases observed during the last five years. In eight cases a staphylococcus was obtained from the urine. It is interesting to observe the much greater incidence of this type of infection in men than in women. In the thirty-four cases reported by Richardson, thirty-three of the patients were men and one was a woman. In the cases seen at the clinic, nine of the patients were men and three were women. Thus in a carefully separated group of forty-six cases, forty-two of the patients were men and four were women.

This coincides accurately with my observations in regard to the tendency to a predominance of men in cases of the cortical type of

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# THIRTY-SECOND REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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*(Continued from page 1124)*

## SURGERY AND DISEASES OF THE NERVOUS SYSTEM

*Sympathetic Ganglionectomy and Perivascular Neurectomy.*—Adson<sup>44</sup> reports an operation which consists of bilateral lumbar sympathetic ganglionectomy, in conjunction with the removal of the sympathetic trunks from above the level of the second lumbar to below the level of the fourth lumbar sympathetic ganglion, with division of all the gray rami, and perivascular sympathetic neurectomy of the common iliac arteries, in order to interrupt all stimuli passing over the sympathetic nerves to the vessels of the lower extremity. Brown, in reporting the results of Adson's work, says that in the cases of spastic paraplegia and Raynaud's disease in which organic disease of the vessels was absent, there was clinical evidence of increased flow of blood and absence of sweating in the feet. Calorimetric studies following operation revealed increases in the rate of elimination of heat from the feet. The superficial temperature was definitely increased as determined by the use of a thermocouple. The duration of the vasodilatation cannot be stated, as the observation periods have not exceeded sixteen months. Similar operations in thrombo-angiitis obliterans were followed by vasodilatation. The feet were warmer, and sweating was absent. Calorimetric studies showed increased rates of elimination of heat and increased superficial temperature of the feet, although the results were not as uniform as those obtained in Raynaud's disease. Pain was completely relieved for the period of postoperative observation, and healing of trophic ulcers occurred in all cases. The blood pressure was not significantly changed.

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44. Adson, A. W.: Ann. Clin. Med. 5:161 (Aug.) 1926.

renal infection. The explanation of this predominance is, I suspect, not to be found in the fact of sex, but in the greater frequency of peripheral infections in men as compared with women, and it may be related to some extent to occupation and trauma.

The natural history of this infection would thus appear to be somewhat as follows: The lesion is generally secondary to a focus of suppuration elsewhere, caused by the pus-producing cocci. The infection is hematogenous in origin and may perhaps be spoken of as "metastatic." The lesion in its typical form is a group of subcortical abscesses, the development of which may give one of three results:

1. The process may be active and overwhelming, producing myriads of abscesses which fuse and cause widespread destruction of the kidney.
2. The lesion may show a tendency to be self-limited, to confine itself to portions of the kidney, and the patient may recover spontaneously.
3. Some relatively circumscribed group of cortical abscesses may continue to develop, break through into perinephritic space and form the typical primary perinephritic abscess, recovery following drainage of this abscess. It is interesting to note that in a relatively small proportion of cases of perinephritic abscesses it becomes necessary to deal with the kidney itself. In no small number of them, fever and renal tenderness persist, indicating, I believe, further cortical suppuration in the kidney; but in the vast majority of cases, the wound continues to drain, the fever finally subsides and study of the function of this kidney shows it to be within normal limits.

*The Pyelitic Type.*—The most common infection of the kidney in the groups defined is commonly referred to as "pyelitis," though it is perhaps more accurate to describe all these cases as "pyelonephritis." It is a condition which has aroused much interest because of its frequency, and there is as yet no wide agreement in regard to its history. On account of its importance, it seems to me justifiable to "take account of stock" periodically to see whether or not any sound deductions can be drawn from the many careful observations which have been made in this field.

*The Infecting Organism:* There has long been considerable agreement in the view that bacilli of the colon group are the causative agents in the majority of cases. In certain subgroups of this condition, it is nearly always the infecting agent. Thus, in the pyelitis of girls it is distinctly rare to find any other organism except in the smallest quantities. In the pyelitis associated with pregnancy, the colon bacillus is the cause in the overwhelming majority of cases. Even if one excludes these two groups, I believe that it is true that the colon bacillus may still be considered the cause in the majority of cases. In a recent study of cases from a clinic in which the pyelitis of children or of pregnancy are rarely seen, and which is therefore a clinic for adults with these

Seven cases of spastic paraplegia, three cases of Raynaud's disease and four cases of thrombo-angiitis obliterans were included in this report.

*Arthropathy in Syringomyelia.*—Ayer<sup>45</sup> reports the case of a man, aged 45, who complained of trouble with the left shoulder and inability to raise the arm above the head. On physical and roentgen-ray examination, there was revealed a well marked neuropathic joint. There was no evidence of tabes. Neurologic examination showed definite dissociation of sensation, leading to the diagnosis of syringomyelia. The interesting feature of the case was the fact that the arthropathy was the earliest symptom of the disease.

[ED. NOTE.—The fact should be emphasized that Charcot joints occur with great frequency in syringomyelia. In fact, the incidence is much higher than in tabes, although the disease itself is less common. The finding of a Charcot joint with no evidence of tabes should of itself point strongly to syringomyelia.]

#### SURGICAL OPERATIONS ON TENDONS, BONES AND JOINTS

*Operative Treatment of Congenital Torticollis.*—Silver<sup>46</sup> describes the method of operative treatment of congenital torticollis which has been used in his clinic for the past eight to ten years. The feature of the operation on which most stress is laid is the excision of one-half to three-quarters inches (1.27 to 1.9 cm.) of the sternal and clavicular heads of the sternocleidomastoid muscle. He insists on the necessity of careful hemostasis and of a postoperative compression dressing. No corrective apparatus is used. Corrective exercises are started as soon as the incision is sufficiently healed. There have been no failures in any of their cases, although the series included one patient who was 17 years of age at the time of the operation.

[ED. NOTE.—We believe there is an element of danger in Silver's opinion that postoperative retention apparatus is unnecessary in these cases, especially for those less conversant with treatment by exercise than he. We have found it necessary in order to prevent recurrence to fix the neck in a position of overcorrection for a considerable period before starting exercises.]

*Operative Treatment of Spastic Torticollis.*—Foerster<sup>47</sup> considers the intradural excision of both the anterior and posterior roots of the first, second, third and fourth cervical nerves as the surest and safest operation for the relief of spastic torticollis. Operations on the muscles are of only temporary benefit, and the extraspinal resection of the nerves is difficult and dangerous. Foerster has performed the intraspinal divi-

45. Ayer, J. B.: Boston M. & S. J. 195:282 (Aug. 5) 1926.

46. Silver, D.: J. Bone & Joint Surg. 8:489 (July) 1926.

47. Foerster, O.: Zentralbl. f. Chir. 53:2804, 1926.

groups excluded, an examination by smear and culture of 201 cases showed the colon bacillus in 141 cases, or 70.4 per cent, and various cocci in 60 cases. Since this is the group about which there is most disagreement, one may continue to agree with the statement often made that the colon bacillus is obviously the infecting agent in from 70 to 80 per cent of the cases.

**Sex:** There is an important predominance of this type of infection in the female, if one considers pyelitis without regard to age. In children, the enormous majority of infections of the kidney of the pyelitic type appear in girls; in fact, pyelitis in boys is a curiosity. If the frequency of pyelitis in association with pregnancy is observed, a large number of cases can be obtained from these two groups. The question requires a further examination of the evidence of the occurrence of pyelitis in the adult not associated with pregnancy. I have reviewed clinical records of the last five years in order to study this point, and I find that in a clinic which, as already pointed out, does not include children nor women during pregnancy nor the puerperium, there are careful records of 259 cases. Of these patients, 178 were women and 81 were men, showing that 68.7 per cent of the cases occurred in women.

The striking predominance of women in this group of cases cannot, I think, be regarded as accidental, and must be of interest to any one who explores this field in an attempt to account for the development of this condition.

#### THEORIES OF ORIGIN

*The Theory of Ascending Infection.*—For a long time, even to the present day, the theory of ascending infection has held sway. This theory received its most important impetus in the attempted explanation of the etiology of pyelitis in girls. Here the anatomic facts of the conformation of the urethra and its obvious exposure to contamination with intestinal discharges formed an easy explanation. If this explanation is to be regarded as sound, it should be shown to be applicable not only to the pyelitis of childhood, but to pyelitis in general, and it must be definitely shown that the process does ascend, which requires clear demonstration of the existence of cystitis at a period immediately antedating the development of pyelitis. Neither of these conditions has been satisfied by the proponents of this view. There is no evidence to show that cystitis in girls antedates pyelitis, and there is overwhelming evidence to show that it does not. An objection to the explanation based on anatomic conformation is found in the fact that a not inconsiderable number of pyelitic infections of precisely the same type occur in men. It seems clear to me that any attempt to explain this infection as one progressively ascending from the urethra to the kidney must be abandoned and other determining factors sought as a basis.

sion in four cases. Three of these are far enough along to be considered end-results, and all are satisfactory. In the fourth case the time since the operation is too short, but the improvement thus far obtained is excellent. In the discussion of Foerster's paper, Bielschowsky called attention to the not uncommon occurrence of torticollis caused by a disturbance in the balance of the oblique muscles of the eye. This form of torticollis begins in early life when the child is being disturbed by double vision. By inclining the head to one side, the weak superior oblique muscles are relieved of strain, and binocular vision is reestablished. Bielschowsky stated that he had seen about twenty cases in which the patients had received prolonged orthopedic treatment without relief until the correct diagnosis was made. The rational form of treatment in such cases is operative reinforcement of the oblique muscles of the eyes.

*Experience with Sauerbruch's Turnover Plastic of the Leg.*—In a former "Report of Progress in Orthopedic Surgery" was given the abstract of an article describing an operation devised by Sauerbruch to replace the femur excised for giant cell tumor by the tibia from the lower part of the leg on the same side. The supply of blood in the tibia was not disturbed, the bone being turned upward so that the malleolar end rested in the acetabulum.

Krampf<sup>48</sup> now publishes the results in the four cases in which this operation has been performed. In two cases the hip joint was spared, and the tibia was merely grafted into the upper fragment. In the two other cases, in which the entire femur was excised, including the neck and head, remarkable functional results were obtained. In one of these cases the turned-over end of the tibia became displaced without disturbing the functional result a great deal; in the other, the end of the tibia which had been placed in the acetabulum was gradually transformed in shape until it came to resemble somewhat the head of the femur.

[ED. NOTE.—We doubt the advisability of such extensive reconstructive surgery as this.]

*Transplantation of the Tensor Fasciae Femoris into the Quadriceps.*—Forbes<sup>49</sup> discusses the possibility of transforming the tensor fasciae femoris muscle from a knee flexor into a knee extensor by transplanting the iliotibial band into the quadriceps tendon. He reports one successful result from this operation.

*Technic of Equalizing Length of Legs.*—Ritter<sup>50</sup> is convinced that in poliomyelitis equalization of the length of the legs is better obtained by shortening of the sound leg than by lengthening of the affected leg. The shorter leg, with small frail bones, offers poor sur-

48. Krampf, F.: Deutsche Ztschr. f. Chir. 196:246, 1926.

49. Forbes, A. M.: J. Bone & Joint Surg. 8:589 (July) 1926.

50. Ritter, R. O.: Surg. Gynec. Obst. 43:93 (July) 1926.

*Theory of Distant Foci.*—The growing appreciation of the importance of foci in various parts of the body as factors in the production of disease in distant parts has naturally entitled this theory to consideration as an essential factor in the production of pyelitis. The foci to which most attention has been attracted are infections of the upper respiratory tract, including the middle ear in children, and in adults infections of the teeth or tonsils, which have been shown to have important relation to other conditions of disease. Other possible foci less frequently considered are those in the gallbladder, appendix or prostate. In order to give this theory high rank in the scale of probabilities, I think it is necessary to show that a causal relation, or at least a possible connection, can be demonstrated in a considerable proportion of the cases belonging to what one might call the three subdivisions of the field: the pyelitis of children, the pyelitis associated with pregnancy and the pyelitis not so associated in adults.

In pyelitis in children there appeared to be an interesting association in the fact that pyelitis is not uncommonly seen in relation to acute infections of the upper respiratory tract as previously defined. The great objection to the acceptance of this view is the fact that the organism producing the infection which is alleged to have a causal relation is practically never the same as that found in the urine. A careful study of this question was made by Helmholz and Milliken.<sup>2</sup> They studied the question with a view to determining whether the organisms obtained from the urine and those from the throats and ears of these children showed any tendency to localize in the kidneys of experimental animals. Their conclusion was that there is no evident causal relation between the infection of the upper respiratory tract and the infection of the kidney. One may, of course, in this case fall back on the assumption of "lowered resistance," but this appears to be rather shadowy.

In the pyelitis of pregnancy, it would be necessary to show that women were more likely to have foci when pregnant than at other times. Finally, it would appear necessary to demonstrate that in persons in whom foci of infection were common, pyelitis was also common. This would, I think, require evidence that pyelitis was a common disease among people in whom neglect of the teeth and catarrhal infections of the upper respiratory tract are common. Evidence in support of this view is lacking. For instance, pyelitis should be exceedingly common in the lower classes in Great Britain and Ireland in whom carious teeth are common. Such a coincidence has not been demonstrated.

I think, therefore, that it is necessary to discard the doctrine of focal infection as an important etiologic factor in the production of pyelitis. It

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2. Helmholz, Henry F., and Milliken, Frances: The Relation of Infections of the Upper Respiratory Tract to Pyelitis, *J. A. M. A.* 81:1160 (Oct. 6) 1923.

gical material, and weight-bearing may not be allowed for a year after the operation of lengthening. A sound femur, on the other hand, may be shortened and be useful in three months. He employs the following technic. After the paralytic leg has been made as long as possible by correction of any contraction, a section long enough to equalize the legs is removed from the normal femur. An intramedullary peg of beef bone is then inserted to hold the fragments in alinement, and it is fixed by pins of beef bone passed transversely through it and the cortex. The muscles shorten and adapt themselves to the new functional requirements. The chief risk is from the formation of hematoma in the loose tissue, which is liable to infection, and this must be watched carefully.

*Fixation of the Crucial Ligaments in the Knee.*—Perthes<sup>51</sup> reports eight cases of operation to restore ruptured crucial ligaments in the knee joint. He has employed a patella-splitting incision to expose the interior of the joint. Then, according to the point of rupture of the ligament, a hole is drilled through the condyle of the femur or the tuberosity of the tibia, and through this hole is passed a piece of aluminum bronze wire, which is looped through the end of the ligament and tied. The wire is then pulled taut and fixed outside the bone. It has been a matter of general opinion that a torn crucial ligament atrophies and even disappears, but this has not been borne out by Perthes' experience. In a case of seven years' duration he has found the ligament still strong and suturable. In seven cases the ligament was avulsed from the femur, and in one from the tibia. In three cases both ligaments were ruptured.

[ED. NOTE.—We believe that fascia provides better material for suture in such cases than wire.]

*Reconstruction of the Patella.*—Valdini<sup>52</sup> reports an experimental and clinical study of the reconstruction of the patella, saying that as greater refinements in diagnosis are made possible, removal of the patella will be performed more frequently and the question of its reconstruction will arise more often. The operation must fulfil certain requirements. 1. It must reestablish the continuity between the quadriceps tendon and the patellar ligament and maintain unchanged the distance between the insertion of the quadriceps and the tibial tuberosity so that flexion will be possible. 2. It must restore the anatomy as nearly as possible so that there will be normal extensor function. The author considers that Dalla Vedova's plastic operation fulfils these requirements. In this operation the patella is removed extraperiosteally. A tongue of the quadriceps tendon, with the base inferior, is next turned down and sutured to the proximal extremity of the patellar tendon and its margins. Then an oval graft, 4 by 3 by 1 cm. in thickness, is taken

51. Perthes, G.: *Zentralbl. f. Chir.* 53:866, 1926.

52. Valdini, P.: *Policlinico* 33:419 (Aug. 15) 1926.

is not necessary, however, to go so far as to maintain that foci of infection may be entirely disregarded in relation to this condition. These foci are obviously objectionable. They may easily influence general conditions and, without promoting disease, may retard recovery. A physician should not, however, hold out to patients the hope that discovery of a definite focus in a tooth or a tonsil will, on its removal, be followed by cure of pyelitis.

*The Doctrine of the Prepared Soil.*—Since I have thus adjudged views put forward in regard to the etiology of this condition as being insufficient to explain the process, it is obviously proper that I should give some theory of my own which may at least form the butt for criticism. The medical profession should be interested in an attempt to explain the natural history of pyelitis by accumulated evidence in regard to the etiology of infection in other portions of the urinary tract. We have been in a position to study accurately the conditions essential to infection of the urinary bladder. From these studies, which have been carried on by many observers and in many countries, the following conclusions have appeared: 1. The introduction of bacteria alone is not sufficient to cause infection of the healthy bladder. 2. The introduction of bacteria associated with moderate trauma will not produce infection. 3. The production of urinary retention with subsequent relief of that retention is the single essential prerequisite to the production of cystitis. It may even be added that in many instances overdistention and release will be followed by cystitis in cases in which there is the strongest evidence that bacteria have not been introduced accidentally.

It seems proper, therefore, to suggest that this same factor may be of importance in the development of infections of the upper urinary tract. This basis for infection of the bladder I have previously referred to as "The Doctrine of the Prepared Soil,"<sup>3</sup> and it seems to me at least arguable that the same doctrine may be applicable to the bothersome question of the etiology of pyelitis. It involves the assumption that as an antecedent to such an infection some abnormal degree of renal or ureteral retention exists. If this doctrine is to be taken seriously, it must be shown to fit in with the facts of the disease as they are known. The outstanding fact is the greater frequency of pyelitis in women: therefore, the question arises whether or not conditions likely to produce renal or ureteral retention are more common in women. There should be, I think, no great difficulty in agreeing that the conditions likely to produce renal retention are considerably more likely to be present in women than in men. Thus the conditions giving rise to visceral ptosis are notably more common in women, and such ptosis is likely to affect

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3. Cabot, Hugh: The Doctrine of the Prepared Soil, *Canad. M. A. J.* **11**:610 (Sept.) 1921.



from the upper part of the inner surface of the tibia. From the patellar ligament a tongue is made with its base superior and turned upward and sutured to the quadriceps tendon and its extensions, thus forming a pocket into which the bone graft is introduced. It is placed with its periosteal surface anterior and its long axis transverse. The pocket is then closed with interrupted sutures of catgut, and the skin is closed. The limb is then immobilized in a plaster of Paris cast which includes the pelvis.

[Ed. NOTE.—We question the necessity of replacing the patella after its excision. Restoration of the continuity of the quadriceps tendon and patellar ligament is alone required.]

*Correction of Bony Deformity by Splintering of the Bone.*—Kirschner<sup>53</sup> gives a report of the experience of his clinic with the morcellation method of correcting bony deformities. By this method the bone over the entire extent of the deformity is cut up into small splinters with a chisel, the cutting being done in the longitudinal and oblique direction. As soon as correction can be obtained the wound is closed and the limb fixed either by a plaster cast or by nail extension. Thus far the operation has been employed in ninety-six cases, with satisfactory results. Kirschner does not believe that the danger of fat embolism is great and has not seen any case in which dangerous symptoms were noted. He considers the risk of infection no greater than with any other corrective operation and less than in those operations in which a fragment of bone is removed and replaced. The time required for union to form is no greater and in many cases is less than with simple osteotomy.

*Fate of Bone Wedge Implant.*—In a case in which a wedge of bone had been implanted in the astragalus by Putti four years before to limit dorsal flexion of the foot, an astragalectomy was performed, and Faldini<sup>54</sup> was able to recover the specimen and to study the implant. While no new articular cartilage had been formed, the graft itself had become to all intents a part of the astragalus and had increased in size. The failure of the first operation was due either to too small size of the graft or to some other technical error, but was not the result of any defect in the general plan of the operation.

*Plastic Surgery of the Os Calcis.*—Schmidt<sup>55</sup> describes a method for the reconstruction of the os calcis after the excision of that bone for neoplasm. A graft was taken from the crest of the ilium, including the anterior superior spine, and was transplanted into the defect, the anterior superior spine being made to serve as a substitute for the tuberosity.

53. Kirschner, M.: Med. Klin. 22:1836, 1926.

54. Faldini, G.: Chir. d. org. di movimento 10:357 (April) 1926.

55. Schmidt, J. E.: Arch. f. klin. Chir. 14, no. 2, 1926.

the urinary tract, particularly on the right side. Conditions favoring renal retention are likely to occur in association with pregnancy. The view may also be accepted that in men conditions favoring renal retention would be likely to occur less often than in women, but sufficiently often to form a basis for infection. The difficulty will come in applying this doctrine to the notoriously frequent occurrence of pyelitis in girls. The occurrence of the disease in girls has, of course, been the stumbling block in every attempt to explain pyelitis, and it must be confessed that at present there is no demonstrable basis for the assertion that renal retention is overwhelmingly more common in girls than in boys. On the other hand, it is true that there is relatively little evidence in regard to the less obvious conditions of the urinary tract in children as compared with adults. The advent of the cystoscope and ureter catheter has given a broadening knowledge of the upper urinary tract both in health and disease, but mechanical difficulties have delayed this investigation in children, and consequently knowledge of the condition of the upper urinary tract in children is not at all complete. Recent evidence has tended to show that in cases of pyelitis in children who do not recover within a reasonable period, there is generally some gross mechanical deformity. Thus in a recent publication, Richard Smith<sup>4</sup> demonstrated an interesting group of cases of chronic pyelitis in children associated with anomalies of development of varying degree or dilatation of the ureter and of the renal pelvis. It is not yet possible to speak with any assurance of the fundamental basis of these dilatations of the ureter which are found in chronic cases, since they may obviously be regarded as either a cause or an effect. It is conceivable that the dilatations which are thus found are the result of a chronic infiltration of the ureter and pelvis from an infection starting in a normal kidney. It is, however, probably true that relatively small degrees of ureteral abnormality would be sufficient to cause retention and start the train which leads to infection and, still further, to dilatation.

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4. Smith, Richard: Roentgen-Ray Examination in Diseases of Children, *Am. J. Dis. Child.* 28:678 (Dec.) 1924.

The achilles tendon was fastened to a periosteal flap from the graft. After ten months the bone was transformed so as to resemble the shape of the heel. The functional result was excellent, the man working as a farm hand.

*Juxtacapital Resection of the First Phalanx for Hammer Toe.*—Bragard<sup>56</sup> objects to the operations for the relief of hammer toe in which the proximal or distal end of the first phalanx is resected. He states that the experience at Lange's clinic has shown that incongruence of the joint surfaces results, leading to the development of a painful arthritis. He recommends as a better method the resection of a piece 1 cm. long from the middle of the first phalanx. This eliminates the contracture of the joint by permitting elongation of the tendons.

[ED. NOTE.—Some of the editors have had a long experience with Goldthwait's operation, in which the distal half of the proximal phalanx of the toe is resected. They have found it a simple and successful procedure. The bad results which Bragard criticizes would appear to have been due to the removal of too little bone. In the operation which he describes the necessity of securing bony union and of maintaining alinement seems to introduce an element of uncertainty which is entirely lacking in the operation of resection of the head.]

#### FRACTURES

*Management of More Common Fractures.*—Allen,<sup>57</sup> discussing the management of the more common fractures, emphasizes the following points: 1. Fractures should receive the serious consideration of every surgeon who assumes the responsibility of handling them. The pitfalls are many, and the results are often disappointing. The sins of commission are frequently more dangerous than those of omission. 2. Take into account from the beginning the patient's occupation and strive to restore him to the economic world. Do not get lost in the maze of treating the bone alone, but treat the patient. The functional result is more important than the anatomic. 3. Free the adjacent joints as early as possible. More dysfunction comes from stiff joints than from the broken bone itself. Active motion and function are the most important physiotherapeutic measures.

*Calcium and Phosphorus Metabolism in Fractures of Bone.*—Ravdin and Jonas<sup>58</sup> have attempted to evaluate the part played by calcium and phosphorus in normal and abnormal ossification. They have studied nineteen cases from this point of view. They have attempted to show that the absorption, excretion and utilization of

56. Bragard, K.: *Ztschr. f. orthop. Chir.* 47:283. 1926.

57. Allen, A. W.: *Boston M. & S. J.* 195:299 (Aug. 12) 1926.

58. Ravdin, I. S., and Jonas, L.: *Ann. Surg.* 84:37 (July) 1926.

# PELVIC ABSCESS IN THE MALE

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Retroperitoneal pelvic abscess in the male is apparently a rare and certainly a very unusual condition. A review of the literature shows that there are only eleven cases thus far recorded, my patient making a total of twelve. From a discussion of the subject with some of my colleagues I am inclined to think that pelvic abscess in the male occurs more frequently than we now believe but often passes undiagnosed. Cases terminating fatally and those recovering but in which the lesion was obscure are not reported. We are here not considering pelvic abscess complicating such diseases as appendicitis, cystitis, prostatitis, seminal vesiculitis and so forth, but only that which occurs as an isolated or metastatic retroperitoneal infection not related to an abdominal lesion. In most of the reported cases of pelvic abscess in the male there was great difficulty in establishing an exact diagnosis because of the indefiniteness of the symptoms. In some a spontaneous rupture of the abscess externally, or into the rectum, was the first objective evidence of the real nature of the disturbance. Yet there is a fairly constant group of symptoms which, while not pathognomonic, is strongly suggestive of a pelvic infection. To this I will call attention later in this article.

## REPORT OF CASE

A structural iron worker, aged 32, fell about 25 feet. He became unconscious and was immediately taken to a hospital. When he regained consciousness several hours later he complained of pain in the left groin. A diagnosis of fracture of the pelvis was made. Three days later he was transferred to the New York Hospital for Ruptured and Crippled and placed in my care. The man was at this time in good condition. He complained of mild pain in the left groin and hip, and because of this discomfort he was unable to walk or lift the left leg from the bed. He had some minor injuries about the face and a fracture of the left pubic bone. The roentgenograms showed a fracture of the ascending and descending rami of the os pubis. There was no great amount of displacement of the fragments and only slight distortion of the pelvis. The rest of the physical examination was negative. There was no blood or pus in the urine, no difficulty with either micturition or defecation and no symptoms or signs referable to the abdomen, back or the extremities. A circular plaster-of-paris pelvic girdle was applied for support, and the patient was kept in bed. The patient was entirely comfortable, and we thought we were dealing with an ordinary case of fracture of the pelvis which usually heals very kindly.

Three days later, that is, on the sixth day after his accident, the patient's temperature suddenly rose to 104.5; he complained of feeling exceedingly miserable, but did not have pain in any special region. An examination several hours after the onset of fever was negative. Particular attention was directed to the abdomen, which was slightly distended, but was soft and not tender. Later in

calcium and phosphorus are not simple problems but highly technical ones. The mere addition of these substances to the diet in the routine case is probably useless. In certain cases deficient retention and fixation of calcium and phosphorus may result in nonunion, but this cannot be foretold from blood serum estimations.

*Fixation of Bone Fragments by Wire Suture.*—Pollidori<sup>59</sup> reports a rather ingenious method of suturing fractured bones with wire. His method is to drill through each fragment about 1 cm. from the fractured end, the drill holes being parallel. He then introduces a wire into the hole in one fragment on the side nearest to himself, carries it through to the other side of that fragment, and then brings it back over the top of the fragments. He then introduces another wire by the same processes, except that in bringing it back to carry it through the hole in the second fragment, it is brought back on the under side of the fragment. In this way he has a cross-suture of wiring on two sides of the fragments, and when they are tightened, which he is careful to do simultaneously, he has an approximation of the fragments, sufficiently secure to hold them in good position unless there is considerable tension on them from strong muscles.

*Fractures of the Surgical Neck and Epiphyseal Separations of the Upper End of the Humerus.*—Conwell<sup>60</sup> feels that fractures of the surgical neck and epiphyseal separations at the upper end of the humerus, if accompanied by much displacement, constitute real but not insoluble problems. This type of injury presents great difficulty in reduction, a fact which is not sufficiently stressed in the literature. Reduction under an anesthetic with the aid of the fluoroscope should always be attempted before open reduction is resorted to. The patient should be treated in bed with traction; in the epiphyseal separations with the shoulder in the position of right angle abduction and 90 degrees external rotation; in fractures of the surgical neck with the shoulder at 45 degrees abduction and 90 degrees external rotation. An abduction splint is used when the patient can be allowed to be up. If open reduction is necessary, foreign material should not be used for fixation; proper reduction and continuous traction is all that is necessary. All splints should be removed as early as possible in favor of active and passive motion and various forms of physiotherapy.

*Pinning Fractured Ulnar Styloid Process in Colles' Fracture.*—Hathaway<sup>61</sup> advises pinning of the ulnar styloid in cases of Colles' fracture, in which after reduction of the radial fracture, the ulnar styloid still remains separated. An ordinary straight bayonet-shaped

59. Pollidori, A.: *Chir. d. org. di movimento* 10:577 (July) 1926.

60. Conwell, H. E.: *J. Bone & Joint Surg.* 8:508 (July) 1926.

61. Hathaway, F. J.: *Brit. M. J.* 2:59 (July 10) 1926.

the day the abdomen became markedly distended and generally tender, but there was no rigidity and no localization of any lesion. This was concurred in by a number of physicians called in consultation. An enema resulted in a large movement but the distention was not relieved, and this in retrospect is significant. During the next four days the temperature receded to 100, but the patient looked and felt very sick. He had very painful tenesmus, and continued to suffer from marked abdominal distention and general tenderness, but he had no rigidity. His blood showed a moderate leukocytosis. Repeated examinations and consultations did not clarify the diagnosis. An infected pelvic hematoma was thought of but, on account of the fall in temperature, the diagnosis was uncertain. Moreover, there was no indication of pointing of an abscess, and had we been sure that there was pus, it would have been difficult to determine its exact location and where drainage should be established.

An examination of the stool at this time, the fourth day of fever, showed some amebae. It could not be determined whether these were pathologic. But since this man some years previously while a sailor had had an attack of amebic dysentery, it was thought possible that he was having a relapse of this disease. Appropriate treatment with emetine was instituted but was ineffective. The symptoms at this time were very confusing to all in attendance. The patient had a low temperature, a moderate leukocytosis with 80 per cent polymorphonuclears, abdominal distention, soreness and tenesmus. He continued to look and feel very sick.

Four days later, that is, eight after the onset of fever and fourteen days after the accident, he suddenly passed a large quantity of pus in the stool. His temperature promptly dropped to normal and he immediately felt complete relief. The temperature has remained normal ever since, and the patient has improved steadily. The abdominal distention persisted for about a week. The pus continued in the stool for about two weeks, but in diminishing amount. Several recent examinations showed no pus in the stool. The patient is now, May 15, 1926, three months after the injury, walking about and apparently well.

The appearance of the pus in the stool with the simultaneous recession of the fever and the immediate improvement in all the symptoms established the diagnosis. This man evidently had a pelvic retro-peritoneal hematoma resulting from the fracture of the left pubic bone. The hematoma became infected and the abscess ultimately ruptured into the rectum. The subsequent course indicates that the abscess has entirely disappeared, and that the wound in the rectum is probably healed. How the hematoma became infected, that is, whether through the blood stream or by proximity to the intestines, is a matter for speculation. So far no evidence has been adduced in my case, nor in any of the others, to decide the exact process of bacterial invasion.

It is interesting, too, to speculate on the cause of the very marked, persistent and distressing abdominal distention which in my case and all the others appeared as a prominent symptom. It has been suggested that the distention is of nervous origin. I assume this means of sympathetic nervous origin. The lesion is, of course, so close to the lumbar and sacral sympathetic ganglions that it is very likely that these organs are irritated by the inflammation. Weight is added to this theory

needle is used for the pin. The author feels that pain and weakness persisting for months after a Colles' fracture is often the result of a failure to secure approximation of a separated ulnar styloid process.

[ED. NOTE.—The editors believe that accurate reduction of the radial fragment automatically brings about approximation of the separated styloid of the ulna in a Colles' fracture. Separation of the ulnar fragment points to a failure to obtain reduction. Efforts should be concentrated on correcting the radial deformity in order to obtain good results. Pinning the ulnar styloid may prove useful in certain complicated cases.]

*Bone Pegging Operations in Fractures of the Neck of the Femur.*—Lexer,<sup>62</sup> who claims to have been the first to employ a bone peg graft for the fixation of the fragments in a fracture of the neck of the femur, in a manner similar to that which was later described by Albee, states that he has largely given up this method because of the fracture and absorption of the graft. He has found it impossible to approximate the fragments so closely that the peg does not have to bridge over a gap. The nutrition of the graft is poor in any case, and especially in the central type of fracture, in which the head is devoid of blood supply. Unless exact adaptation is obtained, connective tissue grows into the gap and leads to the absorption of the graft. The conditions are similar to those in the pegging operation on the ankle joint—Lexer's method. The frequent absorption in such cases, the author points out, is not caused by the synovia, but by connective tissue. In the ankle joint, the periosteum offers a considerable protection against this ingrowth, but in the neck of the femur the conditions are much less favorable. Lexer objects to the publication of results of bone pegging operations on the neck of the femur which do not give exact data on the site of the fracture. Lateral fractures of the neck of the femur may heal well with the peg, but they would heal equally well without it, if the fragments were brought into proper position. He considers that the operation is indicated only under the following conditions: (1) in lateral fractures when the adaptation of the fragments is unsatisfactory, but only after freshening of the surfaces of the fragments; (2) in cases of severe coxa vara. In such cases he advises an incomplete osteotomy of the neck, followed by possible abduction and internal rotation of the leg and fixation of the fragments with a bone peg.

[ED. NOTE.—Henderson has recently published figures which show successful results in 75 per cent of a series of cases of ununited fractures of the hip operated on by the bone pegging method. (See Thirty First Report of Progress in Orthopedic Surgery<sup>63</sup>).

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<sup>62</sup> Lexer, E.: *Deutsche med. Wchnschr.* 52:1115 (July 2) 1926.

<sup>63</sup> Wilson, P. D., and others: *Thirty-first Report of Progress in Orthopedic Surgery*, *Arch. Surg.* 14:150 (Jan.) 1927.

The roentgen-ray and clinical evidence was so clear that it was possible to make a definite diagnosis without a biopsy. Some of the surgeons who saw him believed the condition to be inoperable, so we decided that it was wise to try conservative treatment. He was immediately put on the mixed toxins, supplemented by a massive dose of radium (10,000 millicurie hours) at 7 cm. distance over three different areas. The tumor diminished 5 inches (12.7 cm.) in circumference in the short period of about four weeks, and the patient regained his lost weight. He proved extremely susceptible to the toxins, a very small dose producing a temperature of 104.5 F. In December, 1924, there was evidence of some slight increase in the swelling of the arm, and another radium pack was applied. The toxins were continued once a week until April, 1926.

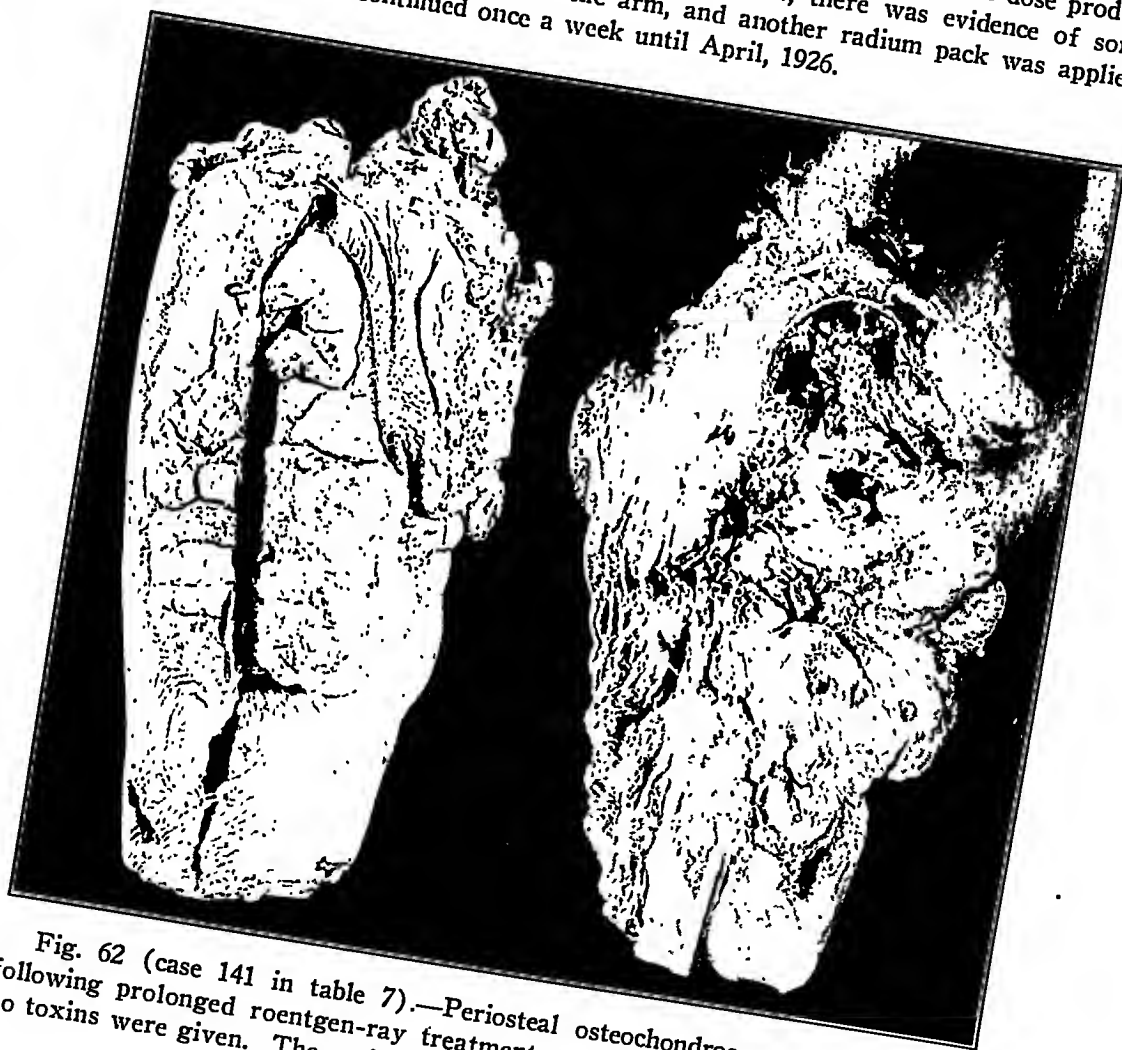


Fig. 62 (case 141 in table 7).—Periosteal osteochondrosarcoma of humerus following prolonged roentgen-ray treatment. Amputation was performed, but no toxins were given. The patient died a year later of metastases in the lungs.

Physical examination in April, 1926, failed to show any evidence of enlargement; the patient's general condition was entirely normal, and he was performing his regular work daily. He is still well, July 30, 1926, two years after beginning treatment. He was able to resume work within two months after beginning of treatment. This case is registered in the Bone Sarcoma Registry as endo-thelioma. It should be noted that in this case the toxins were given directly into the tumor during the early treatment. A roentgenogram taken, Nov. 23, 1926, shows the function normal and no evidence of disease.



CASE 41.—*Recurrent osteogenic sarcoma of humerus; unsuccessful roentgen-ray treatment; removal of tumor followed by amputation; patient died from lung metastases eighteen months later.*

O. B., a man, aged 40, in April, 1923, began to experience severe neuralgic pain in the region of the head of the right humerus; hot applications were applied without relief. One month later, he noticed a diffused swelling at the site of the pain area. In July, 1923, he was operated on at the Union Hospital but no microscopic examination was made. One month later a recurrence was noticed. Physical examination at the time of his admission to the Memorial Hospital showed a recent scar over the anterior aspect of the right shoulder. At each end of the scar was a fungating small mound of vascular tissue with slight serous oozing and crusting. Beneath the scar was a firm discoid mass, apparently lying on the surface of the head of the humerus and more or less adherent to it; there was no adenopathy. The provisional diagnosis was recurrent sarcoma of the head of the humerus.

The roentgen-ray report of Dr. Herendeen, October 12, read: "Stereoscopic films of the shoulder reveal evidence of a destructive process involving the cortex of the anterior surface of the head and neck of the right humerus. The medullary portion of the bone is involved and only a slight amount of bone production is seen. The films lack the features of the usual type of periosteal osteogenic sarcoma or giant cell or central tumor. The appearance suggests a tumor having some of the properties of a chondrosarcoma, with its origin in the greater tuberosity or at the junction of the head with the shaft, and destroying the cortex and involving the medullary cavity with invasion of the soft parts beyond the cortex. The film of the chest does not reveal evidence of metastases to the lungs."

The patient was treated with high voltage roentgen rays from the time of his admission until Jan. 9, 1924. The tumor increased rapidly in size during roentgen-ray treatment. In February, 1924, he was turned over to us for amputation. At this time, physical examination showed the wound badly infected; the tumor had extended beyond the pectoral muscle; the patient's hemoglobin was low; while there was no evidence of lung metastasis, his general condition, and the extent of the tumor led us to regard the condition as inoperable. March 1, a large fungating tumor was removed by Dr. W. S. Stone, who used cautery and knife; the base of the tumor was treated with paste. The microscopic report of Dr. James Ewing was: "There is large spindle and giant cell sarcoma tissue, much inflamed and edematous, covered with diphtheric membrane. The tissue is too much altered to offer an opinion as to the neurogenic origin. No definite osteochondrosarcoma can be made out."

April 24, 1924, Dr. Frank Adair operated, removing the right arm together with a portion of the scapula and clavicle. Following the operation, it was necessary to give the patient a blood transfusion. The microscopic report of Dr. James Ewing then was: "Sections show a large spindle and giant cell sarcoma. The cytoplasm of spindle and giant cells is quite acidophil. The giant cells are of myeloid type, but with multiple multilobed nuclei. There is intertwining of fiber bundles. It is impossible to decide whether this is a periosteal osteogenic sarcoma or a myogenic sarcoma invading the bone; it is probably osteogenic."

Sept. 11, 1925, the patient was visited by the social service worker who reported him to be in very bad condition. The pulse was 132; he had difficulty in breathing, and he refused nourishment. Examination by his local physician revealed involvement of the mediastinum and both lungs; the cough was very profuse. The patient died in the latter part of September, 1925.

*Intertrochanteric Fracture of the Neck of the Femur.*—Under the title "An Epoch-Making Case of Fractured Hip," Marble<sup>64</sup> reports a case of intertrochanteric fracture in a woman, aged 65, who also had severe diabetes and arteriosclerosis. She developed an infection and died seven weeks after the fracture. At autopsy the fracture was found solidly united, with a large amount of callus. It had always been recognized that such fractures united readily, but it had been thought that a considerably longer period was required for healing than appeared in this case. Marble states that the result of this observation has been to shorten the period of fixation in similar cases from twelve weeks to six weeks.

*Operative Treatment of Fractures of the Shaft of the Femur.*—Sherman<sup>65</sup> discusses operative versus nonoperative treatment in fractures of the shaft of the femur. He believes that the objections to the plating operation are based on faulty surgical technic, imperfect asepsis and traumatism in handling tissues. He believes the operative method should be employed whenever it is impossible to secure "a reasonable anatomic restitution which will give a functional result permitting the patient to resume his former employment without disability." He employs an entirely instrumental technic which includes the handling of sutures and ligatures. He emphasizes the importance of using machine screws, and some of the screws should transfix both cortical layers to obtain maximum fixation. The postoperative fixation consists in the application of a Thomas splint with Pierson knee attachment. Plaster is never used. Passive motion of the knee is started in three to four days, and thereafter active motion and physiotherapy are employed. A Thomas caliper weight-bearing splint is applied from seven and one-half to eight and one-half weeks after operation, and is worn for from two and one-half to three months. In his experience, the patients frequently return to light work in four to five months after injury, and resume their former occupation in six months. He never removes the bone plates except for cause. The technic described has been practiced for seventeen years. In a series of seventy cases which he has followed, he has had only one death and that from embolism, no amputations, and no cases of nonunion. In two cases the plates had to be removed on account of infection, but both obtained excellent functional end-results. All patients have returned to their former positions without disability. No patient has ever claimed disability, and no compensation has been paid as a result of loss of function. The author quotes from the published end-results of other surgeons to show that traction methods give results much inferior to these.

64. Marble, H. C.: Boston M. & S. J. 195:549 (Sept. 9) 1926.

65. Sherman, W. O.: J. Bone & Joint Surg. 8:494 (July) 1926

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[ED. NOTE.—Some of the editors have visited Sherman's clinic and have seen many of his late results. They have never seen such uniformly perfect results in a large group of fractures of the shaft of the femur as he has shown. In Sherman's hands the method works well, but the fact should be emphasized that he has had an enormous experience and has been constantly perfecting his technic. In inexperienced hands the operation will yield disastrous results, and no surgeon should attempt to perform it without acquiring the entire technic. As far as the editors are concerned, they prefer to employ skeletal traction and the Thomas splint and reserve the use of the bone plate for the exceptional case. It is to be noted that Sherman advises against open operation after the use of calipers because of the increased risk of infection.]

*Fracture of the Condyle of the Femur.*—Bertocchi<sup>66</sup> reports a case of fracture of one condyle of the femur. In his case the fracture was of the posterior and lateral part of the external condyle. It was caused by violence transmitted from the foot when the knee was semiflexed. He explains that this is due to the fact that when the knee is semiflexed the posterolateral part of the lateral condyle is the most directly in contact with the articular surface of the tibia, and also it is a part of the condyle which on account of its lamellar structure is susceptible to fracture.

*Avulsion Fracture of the Tuberosity of the Fifth Metatarsal Bone.*—Koch<sup>66</sup> calls attention to the necessity in any case of sprain of the ankle of looking for an avulsion fracture of the tuberosity of the fifth metatarsal bone. This is not an infrequent injury and may occur from direct trauma, but much more frequently from a sudden incoordinate contraction of the peroneus brevis muscle as in arresting a sudden inversion of the foot. The injury is particularly likely to occur when a sudden exertion of the foot is required when standing on tiptoe, as may happen in athletic games. Careful roentgen-ray examination should be made in such cases. Confusion with the epiphyseal line or the os vesalianum should be avoided.

#### DISLOCATIONS

*Dorsal Dislocation of the Metacarpophalangeal Joints of the Fingers.*—Reporting the cases of two patients whom he has operated on with good results, Proske<sup>67</sup> describes the dorsal dislocation of the basal joints of the second to fifth fingers. He distinguishes three different types: first, incomplete dislocation, in which the accessory ligament is only stretched or partly torn; second, complete dislocation, in which the ligament is completely ruptured; third, complicated dislocation, in which the ligament is displaced over the metacarpal head.

<sup>66</sup> Bertocchi, A.: Chir. d. org. di movimento 10:429 (April) 1926.

<sup>67</sup> Proske, R.: Beitr. z. klin. Chir. 86:528, 1926.

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In the first two types reduction is possible by closed manipulation, but in the complicated form reduction can be obtained only by opening the joint capsule.

*Dislocation of the Carpal Semilunar Bone.*—Farr<sup>68</sup> publishes the results in twenty-seven cases of dislocation of the carpal semilunar bone. He emphasizes the necessity of early diagnosis, which can be readily made by roentgen-ray examination. In the early cases closed reduction is not difficult and gives excellent results. The end-result of unreduced dislocation is a considerable stiffness of the wrist, with weakness and pain over a long period. In young subjects a certain amount of this disability can be overcome, but a return to anything approaching normal cannot be expected. In Monnard's series of twenty cases immediate reduction gave the best results. There was a return of 90 per cent of motion and 85 per cent of power within nine weeks. Patients treated by open reduction gave the poorest results as regards function and power. Patients with late cases in which treatment consisted of excision showed about 56 per cent of motion and 57 per cent of power after an average period of seventeen weeks.

*Compound Dislocation of the Ulna.*—Corrigan and Corrigan<sup>69</sup> report a case of anterior dislocation of the ulna complicating a fracture of the lower third of the radius. The patient was injured as a result of backfiring while he was cranking his automobile. The crank handle swung round in the reverse direction and struck his arm on the posterior radial aspect. The dislocation was easily reduced after enlarging the opening downward. The triangular fibrocartilage was not sutured. A good functional result was obtained. The condition is rare, and there are few references to it in the literature.

[ED. NOTE.—We have also seen this injury as a result of backfire injury, but the force was applied to the palmar surface of the hand in a dorsal direction; displacing the wrist and radius backward, away from the head of the ulna, the latter being caused to protrude through a wound on the anterior surface.]

*New Method for Reducing Certain Anterior Dislocations of the Shoulder.*—Newton<sup>70</sup> describes a method for reduction of a subcoracoid dislocation of the shoulder, successful after all other methods had failed. He divides the procedure into four maneuvers: 1. With the patient recumbent, the elbow of the affected side is grasped and lifted forward and upward until the arm is almost extended above the patient's head. This relaxes the biceps, coracobrachialis and deltoid muscles. 2. Pressure is then applied to the elbow as in trying to make

68. Farr, C. E.: Ann. Surg. 84:112 (July) 1926.

69. Corrigan, S. H., and Corrigan, C. E.: Canad. M. A. J. (June) 1926, p. 689.

70. Newton, V.: Brit. M. J. 2:157 (July 24) 1926.

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the head of the humerus touch the table. At the same time the operator's fingers are spread out on the back of the patient's shoulder, the thumb in front pressing the head of the humerus downward, helping it travel back under the muscles whence it came. By this maneuver the head travels into a subglenoid position. 3. The patient's arm is now brought down parallel with the trunk. 4. With the operator's clenched fist in the axilla to act as a fulcrum, the patient's elbow is approximated to the side, when the head of the bone reenters the capsule, and will be felt and heard to slip into the glenoid.

#### RESEARCH

*Growth Disturbance Following Resection of Joints.*—Haas <sup>71</sup> shows experimentally that a careful resection of the joint of the knee, in which the entire articular cartilage and a thin layer of adjoining bone is removed, will cause practically no disturbance of growth in length. It is important not to injure the epiphyseal cartilage plate and to refrain from passing fixation sutures through the actively growing columns of cartilage cells. It is advisable not to strip up the soft parts too near to the epiphyseal cartilage plate because of the chances of injuring its blood supply and thereby causing some cessation in growth.

*Autotransplantation and Homoio-transplantation of Cartilage and Bone in Rats.*—In a series of experiments on autotransplantation and homoio-transplantation of bone and cartilage in rats, Loeb <sup>72</sup> was able to demonstrate a definite correspondence between the degree of relationship between donor and host and the severity of the reactions against the transplant on the part of the host tissues, particularly as regards lymphocytic infiltration and the invasion and replacement of transplanted fat tissues by fibrous tissues. With a greater genetic difference between host and transplant, there was in addition a necrosis of bone and of the bone-producing zone of proliferating cartilage cells. When the genetic difference is not great the regenerative function of the perichondrium is not interfered with; when the difference is great, the regenerative function of the perichondrium is inhibited, though not entirely prevented.

*Rôle of Bone Marrow in Regeneration of Bone.*—In order to determine the part played by the bone marrow in the regeneration of bone, Willich <sup>73</sup> has performed a series of animal experiments. A gap was made in the radius or ulna by the removal of a portion of bone with its periosteum. These defects were then filled with bone tissue of different sorts. From a study of the reparative processes the following conclusions were reached: The bone marrow is the most viable of

71. Haas, S. L.: Arch. Surg. **13**:56 (July) 1926.

72. Loeb, L.: Am. J. Path. **2**:316 (July) 1926.

73. Willich, C. T.: Beitr. z. klin. Chir. **136**:102, 1926.





bone tissues. It rapidly forms young bone, and within a year complete regeneration has taken place. Compact bone without periosteum is rapidly absorbed except for small remnants, whereas with the periosteum the absorption is somewhat delayed. Without marrow and endosteum the regeneration is slow and incomplete. According to these experiments, marrow and endosteum are the most important materials in bone transplantation.

*Transplantation of Bone into Joints.*—Haas,<sup>74</sup> believing that there has been no convincing proof or satisfactory demonstration of the growth of bone outside the body, has performed some experiments in which he transplanted pieces of bone inclosed in rubber tubing into a joint. He found that bone fragments placed in perforated rubber tubing and inserted into a joint remained viable and were able to produce sufficient new bone to form a union between the fragments. There was no evidence that the foreign bodies caused any injury to the articular cartilage. In all the experiments the foreign bodies became adherent to the synovial membrane.

*Removal of Particulate Matter from Joint Cavities.*—Key<sup>75</sup> reports an experimental study of the mechanism by which waste material is removed from joint cavities. In the wear and tear of everyday use, bits of the cartilage or synovial surfaces are detached and set free in the synovial cavity. In order that joints may continue to function normally some mechanism for the removal of this waste material is necessary. The material used for injection was Higgins' American India ink, a coarse colloidal solution of carbon. The experimental animals were adult rabbits. The injections were made in both knee joints. The animals were killed at intervals of from 1 to 104 days after the injection. From his studies, Key concludes that the carbon was removed from the joint cavity by four different methods: 1. Some carbon passed directly through the synovial surfaces. 2. Some carbon particles entered the lining cells of the joint. 3. Some was phagocytosed by leukocytes and macrophages and carried out into the subsynovial tissues. 4. Fibrin clots containing carbon became adherent to the synovial membrane and were excluded from the joint cavity by a disappearance of the old synovia and ingrowth of new synovia across the free surface. An interesting observation was that some of the particles were carried into the interior of the bony substance by macrophages within a few hours after injection. One wonders whether the same process may not also apply to invading bacteria.

74. Haas, S. L.: Transplantation of Bone into Joints, Arch. Surg. 13:426 (Sept.) 1926.

75. Key, J. A.: J. Bone & Joint Surg. 8:666 (July) 1926.



*Investigation of Strength of Certain Materials Used for Operative Fixation.*—Lange <sup>76</sup> has investigated the strength and elasticity of certain materials commonly used for autoplasmic and alloplastic operations and has reached the following conclusions. The strength of the compact bone of the tibia is one-fourth less than that of beef bone. The strength of a tibial graft composed of cortex and spongy bone is three or four times less than that of beef bone. The absorption of a beef bone graft begins much later than that of a tibial graft, the latter reaching the maximum of mechanical weakness about twelve or fourteen weeks after the operation. For use in the femur or humerus the beef bone graft seems superior to the tibial graft on account of its greater strength. As the tibial graft surpasses the beef bone graft, however, in its bone-forming power, the simultaneous use of both kinds of material may at times be desirable. Of the kinds of wire commonly used, Lange finds that iron wire has the greatest firmness, and the Krupp steel wire the greatest elasticity. Celluloid is about as strong as bone; repeated sterilization increases its strength, but decreases its elasticity. Silk has greater resistance than fascia. In general, alloplastic materials are shown to be stronger than autoplasmic materials, and since there is no greater risk attached to the use of one than the other, the former are to be preferred for purposes of operative fixation. The experience of the orthopedic clinic at Munich, where alloplastic materials have been used extensively, is cited to show that bad results from their use have not been encountered.

[ED. NOTE.—It should be pointed out that the factor of strength is only one of many factors to be considered in selecting the fixative material to be used in an operation. It all depends on the requirements. We are sure that autoplasmic materials meet the physiologic requirements better than alloplastic materials, and for this reason they should have the preference whenever possible.]

*Infectivity of the Bursa in Hallux Valgus.*—A few years ago Wymer stated that in his opinion infection in wounds following operations for hallux valgus was usually caused by organisms contained in the inflamed bursa. To establish the accuracy of this opinion Pick <sup>77</sup> has made a bacteriologic investigation of the contents of the bursa in a group of cases. The results were negative in all but three cases, in which the cultures showed the growth of a few cocci, in all probability the result of contamination. All the bursae which were examined showed marked evidence of inflammation, including redness, swelling and tenderness. He concludes that in general the contents of these bursae may be considered sterile.

76. Lange, M.: *Ztschr. f. orthop. Chir.* 47:345, 1926.

77. Pick, H.: *Zentralbl. f. orthop. Chir.* 54:70, 1927.

changes in the bone taking place. Accordingly, an amputation was performed, November 25, at another hospital. The amputated leg was brought to the Memorial Hospital and a careful microscopic examination was made by Ewing, who reported as follows:

"Just below the tibial tubercle is an ulcerated area 3 by 4 inches (7.6 by 10.1 cm.) involving the tibia to a depth of 2 mm., but the bone is hyperemic to a depth of 5 mm. Vertical section of the leg shows the tibia to be the seat of a medullary tumor, involving irregularly the upper two thirds of the shaft. The marrow tissue is opaque, with minute foci of necrosis and much hyaline tissue. The shaft is irregularly thickened by a deposit of new bone from the periosteum, and several chalky bone spiculae run from the inner surface of the bone into the marrow. There is a fusiform tumor swelling involving the periosteum over the upper half of the tibia, the thickest portion of which is about 2 cm. Just below the joint surface of the inner tibia tuberosity, the shaft is perforated by soft tumor tissue which invades the muscle at this point. Sections from various portions show cellular tumor tissue composed of medium large polyhedral cells, surrounded by blood vessels or lying in columns in dense fibrous tissue. There are numerous areas of complete necrosis, of tumor tissue and bone trabeculae. At the head of the tibia, the tumor is more cellular. Many of the trabeculae of the cancellous tissue appear necrotic."

In June, 1925, four and one-half years after the beginning of treatment, or one and one-half years after the amputation, the patient was reported to be in good health, with no evidence of a recurrence. The patient died of metastases in the lung in November, 1925.

The following case illustrates the extreme difficulty of making an early diagnosis in certain cases of sarcoma of the long bones:

CASE 43.—*Endothelial myeloma of femur; amputation; toxins; well one year.* A. M., a man, aged 30, was admitted to the New York Broad Street Hospital in August, 1924, where a clinical and roentgen-ray diagnosis of osteomyelitis was made. The report of the roengenologist stated: "There is evidence of cavitation in the central portion of the shaft of the right femur in its anterior surfaces, which is the result of osteomyelitis. The periosteal surfaces of the patella are irregular, and the periosteal surfaces of the femur at certain places show marked irregularity. The diagnosis points to a chronic osteomyelitis." An exploratory operation was performed and a microscopic diagnosis of chronic osteomyelitis was made.

The patient, still having trouble with the leg, was admitted to the Hospital for Ruptured and Crippled, Jan. 23, 1925, in Dr. Royal Whitman's service. Various blood tests proved negative. Physical examination showed a long scar on the outer aspect of the lower third of the right thigh. On the outer surface beneath the scar, there was a certain resistance and some sensitiveness to pressure. Roentgen-ray examination showed at a point about the junction of the middle and lower third of the femur a cavity apparently containing dead bone. The area of disease was about  $2\frac{1}{2}$  inches (6.2 cm.) in length and occupied nearly the entire section of the bone at this point. The diagnosis was osteomyelitis.

An exploratory operation was performed by Dr. Whitman, January 26, a 6-inch (15.2 cm.) incision being made through the old scar. The diseased bone was immediately encountered. The interior cortex cavity was about  $2\frac{1}{2}$  inches long and sharply defined. The cortex of the bone was removed; cheesy, half-coagulated, albuminous contents were removed. The interior was swabbed with tincture of iodine. A large muscular flap of the vastus externus was sewed into the cavity. The wound healed promptly. Another Wassermann test proved negative.

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lowing the operation, and a smaller one the next night; his pain seemed somewhat improved.

The patient was readmitted to the hospital, June 20. At this time he complained of a great deal of pain; there was a marked swelling about the incision, which was semifluctuant but not tender. There was a hard gland in the inguinal region about three-fourths by one-half inch (1.8 by 1.2 cm.). His general appearance was cachectic.

Roëntgen-ray examination, July 11, showed that proliferative bony change had taken place. There also was a very definite lifting and proliferation of the periosteum, particularly from the portion of the femur below the site of the disease. July 17, the patient was seen in consultation by one of us (W. B. C.) and a diagnosis of sarcoma was made. An immediate amputation was advised, but to this the patient would not consent. July 21, an exploratory operation was performed by one of us (B. L. C.), which revealed a soft tumor that communicated with the anterior bone; this was curetted under local anesthesia and submitted to Dr. Jeffries for microscopic examination; he reported sarcoma. The microscopic report of Ewing was malignant tumor of the bone marrow, probably endothelial myeloma.

A pathologic fracture later occurred. In view of the large size and rapid growth of the tumor, an immediate amputation was again urged, and performed by one of us (B. L. C.), July 31. Prophylactic toxins were given after operation and the patient is well, July 30, 1926, one year later.

#### CASES OF CENTRAL MALIGNANT SARCOMA.

*CASE 44.—Periosteal sarcoma of tibia with metastases in lung; metastases controlled by roentgen-ray treatment alone for nearly two years; patient in hopeless condition in April, 1926.*

S. F., a woman, aged 41, was admitted to the Memorial Hospital in July, 1922. At the age of 14, or twenty-seven years before, the patient noticed a slightly diffused swelling of the right tibia accompanied by pain so severe as to cause her to limp. Three years later an operation was performed at St. Catherine's Hospital, Brooklyn (no microscopic examination). There was no sign of a recurrence until about five years before admission, or twenty years after the operation, when a persistent, sharp pain was felt at the site of the primary growth, followed shortly after by a swelling of the tibia, which steadily increased in size. In April, 1922, a second operation was performed by Dr. E. A. Parker.

The microscopic report was alveolar sarcoma, with the periosteum involved. This diagnosis was confirmed by Ewing, who pronounced it an osteogenic sarcoma. According to Dr. Parker, the roentgen rays showed roughening of the periosteum. On operating, he found a large, soft, very vascular mass; the periosteum was roughened. July 19, he made another incision, finding no pus, and he regarded the mass then present to be a recurrence.

Roentgen-ray treatment was given at the Memorial Hospital from July 24, 1922, to Jan. 5, 1923, nine exposures. February 6, Dr. R. E. Herendeen reported that the roentgen rays revealed evidence of sarcoma metastases in the lung, and that there was evidence of more production of bone seen in the plates of the head of the tibia.

April 9, 1926, the patient had had a marked recrudescence of the metastatic tumors and was going down hill rapidly.

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and the wound was closed. Shortly after the operation, the mixed toxins were begun by Dr. Lilienthal and the treatment was later carried out by Dr. I. Nadel under our direction.

We examined the patient, June 23, and found her in excellent condition. It was necessary for her to go west shortly after and the toxin treatment was resumed by Dr. Stanley Stillman of San Francisco, and kept up for nearly six months longer. Dr. Stillman sent us a series of roentgenograms taken in February, 1923, showing a perfectly normal condition. Her general and local condition has remained normal up to the present time, and there is no evidence whatever of a recurrence, now more than four years later. She was personally examined by one of us (W. B. C.) in May, 1926, and no evidence of disease could be found.

The microscopic report of Dr. F. S. Mandlebaum of Mount Sinai Hospital, March 30, was: "Microscopic examination of tumor removed from tibia shows an osteosarcoma, not the so-called giant cell sarcoma. The small specimen excised from the periosteum is free of tumor." Dr. Ewing's diagnosis was giant cell sarcoma.

*CASE 46.—Central sarcoma of tibia; clinical and roentgen-ray diagnosis: giant cell sarcoma; microscopic diagnosis, telangiectatic sarcoma.*

M. G., a woman, aged 35, with a negative family history and general health good, had a history of repeated local trauma. In May, 1920, the patient was injured in a taxicab collision; there was no definite local injury. In May, 1921, she fell, injuring her left knee, two months after which she noticed pain and swelling. In December, 1921, she was treated by baking and massage, and in the following March the leg was put in a plaster cast, which was worn for two months.

The patient was admitted to the Memorial Hospital, June 13, 1922, at which time physical examination showed a large tumor of the lower end of the femur apparently of central origin. The roentgen-ray diagnosis was giant cell sarcoma. A large dose of radium in the form of a pack (6,249 millicurie hours at 6 cm. distance) was immediately applied and in addition she received a brief course of toxins (thirteen injections in three weeks). This was supplemented by four exposures of high voltage roentgen rays. May 30, 1924, when she was readmitted to the Memorial Hospital, physical examination showed the tumor to have markedly increased in size; there was evidence of a pathologic fracture; the patient had been unable to walk for the last eight months. June 5, the leg was amputated.

The pathologic report of Ewing was: "The tumor occupies the upper end of the tibia. It measures 14 cm. long by 15 cm. wide by 15 cm. anteroposterior. It shows a bony capsule nearly complete enclosing the whole growth, but crackling in many places. The skin is everywhere intact. On gross section the tumor is found to be composed of a series of cystic cavities, 1 to 4 cm. wide, filled with blood clot and serous fluid, lined by necrotic tumor tissue in rather thin masses. Many of these masses contain bone. The gross appearance indicates necrosis of nearly the whole central mass of the tumor. The supposed growth has been due to progressive aneurysmal dilatation of the dilated sinuses. The joint surface is everywhere smooth but there are numerous small elevations projecting into the joint covered with synovial membrane and hyperemic bone tissue. The shaft of the bone ends sharply at the lower edge of tumor, but blood spaces extend 2 cm. lower in the medullary cavity. The gross diagnosis is telangiectatic osteogenic sarcoma.

Considerable portions of the tumor are composed of giant cell structure in which the giant cells are rather small and few, and supporting cells rather large and hyperchromatic. This type of tissue lines many sinuses. About many sinuses

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An exploratory operation was performed in the latter part of March; the tumor was found to involve the upper portion of the femur; a piece was removed for microscopic examination and pronounced perithelioma by Dr. Mandlebaum. After further study his final diagnosis was plasma cytoma, the tumor originating in the bone marrow and chiefly made up of plasma cells. He believed the tumor to be malignant and of bone marrow origin.

A pathologic fracture occurred while the patient was in Mount Sinai Hospital, followed by complete loss of power in the left leg and partial loss in the right leg, pointing to probable involvement of the spine. The condition was therefore regarded as absolutely hopeless and the patient was referred to the House of Calvary (a home for incurable cancer patients) in the early part of July. The patient's husband, who had been referred to us by Dr. Robert T. Morris, consulted us in the hope that something might be accomplished by the toxin treatment. After obtaining a careful history from Drs. H. Neuhof and Douglas Quick, we gave an absolutely hopeless prognosis, and advised against bringing the patient to the hospital. However, on the urgent plea of the husband, we finally consented to examine the patient. She was then brought in an ambulance to the Memorial Hospital, in July, 1921.

Physical examination on her admission showed a tumor involving the upper half of the left femur; the patient was greatly emaciated and unable to move the left leg; there were marked limitation of motion of the right and numbness in both legs. Examination of the upper third of the left femur showed marked bony enlargement with pathologic fracture; the leg was put up in a Buck's extension; the plaster cast was removed. Roentgen-ray examination showed a tumor involving the upper third of the femur, about 7 inches (17.7 cm.) in length, with a pathologic fracture in the center. The tumor apparently was of central origin, although so much of the bone was destroyed that it was impossible to tell whether the tumor was of periosteal or central origin. The roentgenogram taken on her admission showed that marked increase in the destructive process had taken place since the previous picture taken in March; no picture was taken of the spine.

We still felt that the condition was hopeless and so told her husband; but as the patient had come such a long distance it did not seem right to send her home without any treatment, and so the toxins were started in small doses, which were gradually increased up to the point of producing severe reactions. Marked improvement was noted at the end of two weeks. A roentgenogram taken at the end of the month showed local improvement and no further extension of the disease; there was beginning regeneration of the bone. In the middle of September, 1921, one radium pack treatment was given in addition to the toxins. Union at this time was sufficiently firm to justify removal of Buck's extension, and the leg was put up in plaster-of-paris. By the latter part of November, union was so firm that a Thomas splint was ordered; the patient was then able to get about in a wheel chair; she had gained 20 pounds (9 Kg.) in weight. Roentgen-ray examination, Jan. 19, 1922, showed well marked regeneration of the bone with firm union. The patient gradually recovered the use of her legs and by March, 1922, she was able to walk with the aid of crutches. The toxins were kept up for nearly a year. She was shown before the New York Surgical Society in March, 1923. The microscopic report of Ewing was endothelioma myeloma.

In the fall of 1923 there was evidence of renewed activity of the disease; the patient refused to take further treatment; metastases developed, and she died in December, 1923. In this case we believe that if the patient could have been kept under treatment much longer, instead of stopping at the end of six months, the result might have been different.

CASE 42.—*Endothelioma of tibia; partial control of disease under radiation; later evidence of further progress; amputation; patient well one and one-half years later. (Patient of Dr. James Ewing.)*

A. V., a boy, aged 17 years, had a negative family history and had suffered no trauma. During the year 1919, he felt intermittent aches and pains, which became more intense and were followed a couple of months later by a swelling of the tibia in the region of the upper third; there was no ulceration or redness. In November, 1920, an exploratory operation was performed for supposed osteomyelitis. The patient was admitted to the Memorial Hospital, Dec. 8, 1920. The roentgen-ray report of Dr. R. E. Herendeen stated: "Evidence of considerable proliferation in the periosteum of the upper end of the tibia is observed. There is no evidence of active bone destruction present. The medullary canal here is somewhat expanded."

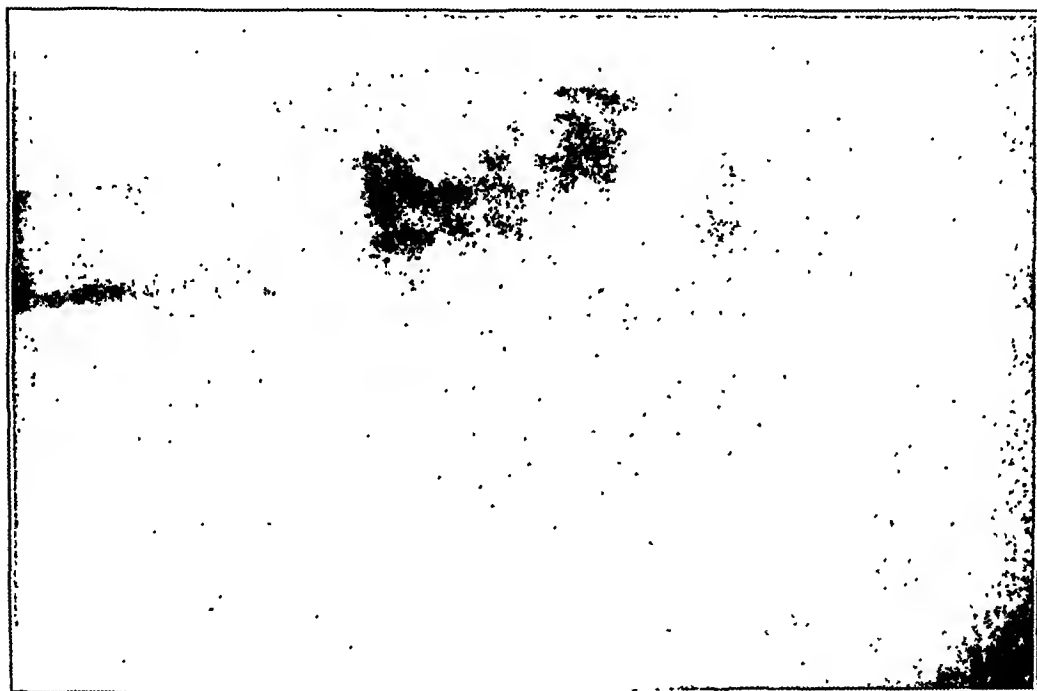


Fig. 63 (case 142 in table 7).—Telangiectasia of humerus; treated with roentgen rays; amputation; no toxins; patient well two years later.

The microscopic report of Dr. Ewing on sections from the exploratory operation in November, 1920, stated: "This is a diffuse cellular tumor composed of small polyhedral cells without stroma. The cells show clear cell bodies, but material is crushed except in one portion. On this the diagnosis of diffuse endothelioma is based."

The patient was treated with radium in the form of a pack applied at 6 cm. distance; from Dec. 9, 1920, to May 16, 1923, he received a total of 91,191 milli-curie hours. Definite improvement in the local condition followed radiation. Nov. 8, 1923, a biopsy was performed by Drs. W. S. Stone and Douglas Quick. The microscopic report by Ewing was endothelioma, with perithelial growth in dense scar tissue.

In November, 1923, the growth showed evidence of renewed activity; the patient complained of increasing pain and the roentgen rays showed probable

From Oct. 23, 1923, to May 12, 1924, the patient received nine exposures of low voltage roentgen rays. In addition the radium pack was applied, 10,000 millicurie hours at 10 cm. distance over three different areas, Feb. 3, 1924, making a total of 30,000 millicurie hours; April 15, he received 37,000 millicurie hours at 10 cm. distance and, April 21, he received 5,000 millicurie hours over two different areas (total 10,000 millicurie hours), making a grand total of 77,000 millicurie hours.

The patient did well until February, 1924, when the swelling of the ankle showed marked increase in size and there was evidence of enlargement of the inguinal glands. Pain soon developed throughout the entire body, and roentgen-ray examination in May, 1924, showed evidence of general metastases. The patient died May 14, 1924. A necropsy was performed, revealing very extensive metastases in nearly every bone and organ.

*CASE 50.—Osteogenic sarcoma of femur; treated with high voltage roentgen rays without control of disease; rapid progress of disease.*

P. G., a girl, aged 14½ years, with a negative family history, had no history of trauma. In September, 1924, she first felt pain in the lower end of the left thigh; this was not severe at first, but about two months later it became more so, causing the patient to limp. She was soon confined to bed and was treated with local applications. A physician was then consulted, who called Dr. L. T. LeWald in consultation; the latter made a diagnosis of osteogenic sarcoma. She was treated with high voltage roentgen rays, two exposures one hour each over the tumor, and one treatment over the chest anteriorly. The pain became so intense as to keep her awake nights. Jan. 21, 1925, she was admitted to the Memorial Hospital, at which time physical examination showed a large, fusiform swelling of the lower fourth of the left thigh, fixed to and apparently arising from the femur; it was extremely tender to touch. The left leg could not be fully extended. There also was an enlargement of the head of the left tibia. Roentgen-ray examination by Dr. R. E. Herendeen showed an osteogenic sarcoma of the distal third of the left femur, with no evidence of metastases in the lungs.

February 11, a ligation of the femoral artery was done by Dr. F. E. Adair.

Roentgen-ray examination, February 28, showed evidence of considerable increase in the size of the tumor of the knee when compared with previous films: there was no definite evidence of lung metastases. The patient was treated with high voltage roentgen rays to the chest and femur for a period ranging from January 26 to June 3, 1925. Roentgen-ray examination, May 18, revealed evidence of considerable increase in ossification of the tumor, which appeared to be very definitely encapsulated. The roentgenogram of the chest revealed evidence of large metastatic tumors. She grew worse rapidly and died, July 4, 1925.

In order to show the striking results obtained in inoperable malignant sarcoma of other bones, we have included the following three cases (cases 51, 52 and 53) but they are not strictly speaking long bone cases.

*CASE 51.—Osteogenic sarcoma of first rib; clinical and roentgen-ray diagnosis; radium and toxin treatment, patient well eight years later.*

H. M., a girl, aged 15 years, was referred to us by Dr. John H. Gibbon of Philadelphia in March, 1917. One year before the patient had what was supposedly an attack of influenza; following this she was subject to a recurrence of pain in the left shoulder. In November, 1916, she had a neuritis-like pain in the left shoulder which lasted for about one week. In the latter part of

The microscopic report of Dr. F. M. Jeffries was chronic osteitis, with no evidence of neoplasm.

April 11, 1925, the patient had had little pain since he had been in the hospital. The pain was not referred to the point of the osteomyelitis but to the sole of the foot; no rise in temperature had been observed. April 18, 1925, the patient was readmitted to the Hospital for Ruptured and Crippled, complaining of local pain; there was a swelling and fluctuation beneath the old incision.

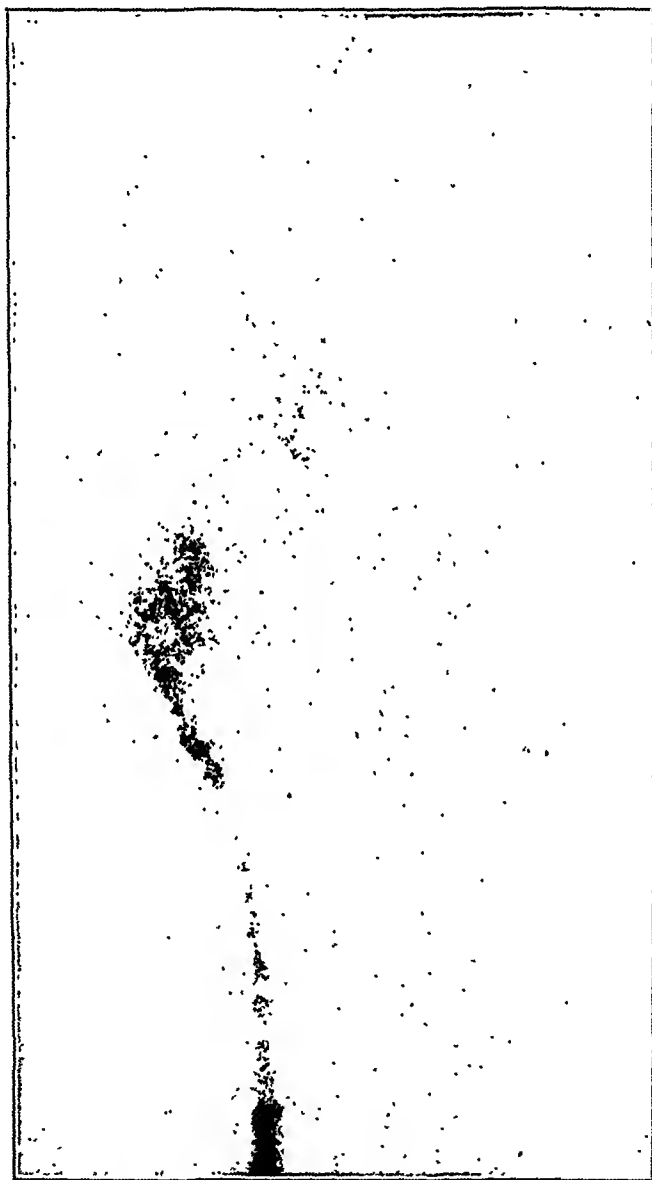


Fig. 64 (case 155 in table 7).—Clinical and roentgen-ray diagnosis: giant cell tumor of tibia; microscopic diagnosis: central sarcoma, probably malignant. Amputation was followed by toxins. The patient was well one year later.

A third exploratory operation was performed by Dr. Whitman, April 20; an incision was made through the former scar; no pus was encountered. The muscles were separated, and from the interior of the bone a large quantity of grumous material flowed out under a state of some tension. The wound was packed with iodized gauze. The patient had a considerable hemorrhage on the night fol-



destructive process of the eighth rib, which is less dense than in previous films. This skiagraph also shows evidence of reproduction of the vertebral end of the rib. There appears to be some involvement of the seventh and ninth ribs; this involvement was also observed in the previous films, but not as clearly as in this skiagraph. The diagnosis is sarcoma of the eighth rib, which shows definite bone production."

There was no evidence of lung involvement. The patient had been receiving roentgen-ray therapy at the Jewish Hospital. She was referred to us by Dr. Cook, Dec. 4, 1922. We advised supplementing the roentgen rays with injections of the mixed toxins of erysipelas and *Bacillus prodigiosus*. These injections were begun at once and continued at home by Dr. Cook under our direction until November, 1923, or for nearly one year. A roentgenogram taken in July, 1925, showed the disease to be apparently under complete control. The patient's general health was excellent. She was well in April, 1926, after nearly four years.

CASE 53.—*Periosteal sarcoma of the mastoid; treated with toxins and roentgen rays; patient well ten years later.*

G. P., a boy, aged 14 years, was referred to us by Dr. F. B. Lund of Boston, Aug. 14, 1916. A tumor just behind the ear had been excised by the local physician in December, 1915; the clinical diagnosis was a wen; the microscopic diagnosis, a rapidly growing sarcoma with numerous mitotic figures. A slight recurrence took place early in January, 1916. The patient was seen by Dr. H. A. Kelly, who believed the growth could be controlled by radium. Two radium treatments were given by Dr. Kelly. The disease again rapidly recurred and in February, Dr. Lund excised the growth, removing the outer table of the skull. The recurrence had taken place in the scar of the former operation; the growth apparently originated in the periosteum. Another recurrence took place some time later and, June 1, a third operation was performed by Dr. Lund, who opened some mastoid cells. This growth was in front of the one formerly removed and was located nearer the ear. "In cutting beneath it some of the cells were spilled." The growth appeared encapsulated, but was very soft and jelly-like. The disease again recurred, this time nearer the ear, and a fourth operation was performed by Dr. Lund, who opened up the mastoid cells extensively and went into the mastoid antrum.

Shortly after the operation, Dr. Lund started the patient on mixed toxins, beginning with one-half minim once a week and gradually increasing the dose up to 5 minims, without obtaining a reaction. August 14, the patient was referred to us for further toxin treatment; he remained at the hospital for about two months, during which time he received twenty injections, the dose being increased to the point of producing a reaction temperature of 103 F. During the early part of his stay he was given two or three roentgen-ray treatments over the mastoid region.

Physical examination at the time of his entrance to the Memorial Hospital showed in the center of the cicatrix just behind the mastoid region an area about an inch in diameter which was believed to be a recurrence. The toxins were kept up for nearly a year by the patient's home physician, the patient coming down and reporting to us for examination and direction at frequent intervals. He is in excellent condition at the present time, ten years later.

In this case the microscopic diagnosis of Dr. E. B. Mallory was periosteal sarcoma; of Dr. James Ewing, periosteal osteogenic sarcoma.

CASE 45.—*Sarcoma of tibia, central, malignant, osteogenic; exploratory operation followed by prolonged toxin treatment; limb saved; patient well four years later.*

A. L., a woman, aged 22, was referred to us by Dr. Howard Lilienthal of New York in June, 1922. The patient had consulted Dr. Lilienthal in March, 1922, at which time she had a swelling of the left tibia just above the ankle;

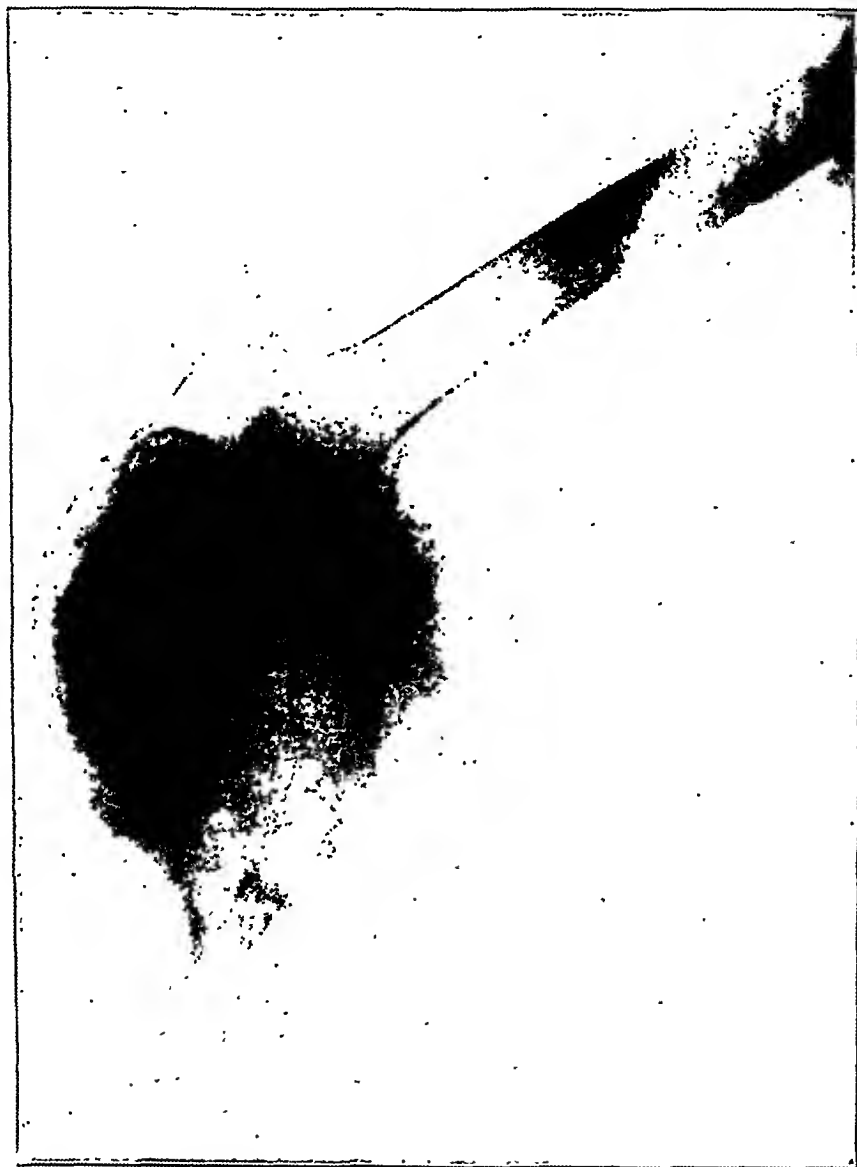


Fig. 65 (case 155 in table 7).—Two years later than figure 64.

there was no pain and only slight lameness; there was no history of trauma. Roentgen-ray examination showed a tumor of central origin with considerable expansion of the lower end of the tibia; the bony shell apparently was not broken through. From the roentgenogram it was believed to be a giant cell tumor.

An exploratory operation was performed by Dr. Lilienthal in March, 1922, revealing a central tumor, about 3 inches (7.6 cm.) in length, with marked expansion of the bone. After curettage a transplant of fat was inserted in the cavity,

# OVERGROWTH OF THE LONG BONES OF THE LOWER EXTREMITY

REPORT OF THREE CASES \*

MAXWELL HARBIN, M.D.

CLEVELAND

Overgrowth of the long bones resulting in asymmetry is an old observation. Since the roentgen ray has come into general use there have been a greater number of case reports with more accurate observations than formerly. The roentgen ray has been the means, furthermore, of conducting experimentation in an effort to explain the etiologic factors.

The purpose of this article is to describe three cases of overgrowth of the lower extremity, with a distinctly different etiologic factor in each case. All represent an involvement of the tibia in children between the ages of 12 and 14 years.

## FACTORS THAT INFLUENCE THE GROWTH OF NORMAL BONE

Normal growth of bone varies with the physiologic demand of the organism for it. Nature seems to provide some mechanism whereby a constant symmetrical progression takes place. Osteoblastic cells located on the proximal portion of the epiphysial line have the quality of proliferation in a linear fashion, resulting in growth in the long axis, while the periosteal cells contribute to enlargement in a transverse diameter.

It seems that the activity of the osteogenic cells may depend on a chemical stimulus which exerts its effect on the epiphyses. The relationship, however, of blood supply is perhaps of greatest importance and its variation serves to explain certain abnormal changes in growth. The experimental studies of Haas <sup>1</sup> have demonstrated the importance of the integrity of the vascular supply to normal longitudinal growth.

## FACTORS THAT PRODUCE ABNORMAL GROWTH OF BONE

Various diseases of the bone such as rickets, osteomalacia, osteitis deformans and syphilis, chronic or acute illness, chronic infections localized in or about the metaphyseal portion of the long bones, the action of various glands of internal secretion, trauma and the influences of the nervous system may alter the growth of bones. Perhaps one of the most common types of overgrowth of a single extremity and sometimes of a single bone is that which occurs in adolescents who have

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\* From the Department of Surgery of the Lakeside Hospital and the Western Reserve University School of Medicine.

1. Haas, S. L.: The Relation of Blood Supply to Longitudinal Growth of Bone, *Am. J. Orth. Surg.* 15:157 (March) 1917.

the cells are quite large and hyperchromatic but nearly as atypical as in ordinary telangiectatic sarcoma. There is much bone formation in small trabeculae and of rather normal appearance. Some areas show much hyaline material. There are no areas of typical malignant osteogenic sarcoma. The impression is drawn that this is mainly a tumor of dilating aneurysmal blood vessels, with giant cell reaction and new, mostly reparative bone formation. The malignancy appears to be mod-

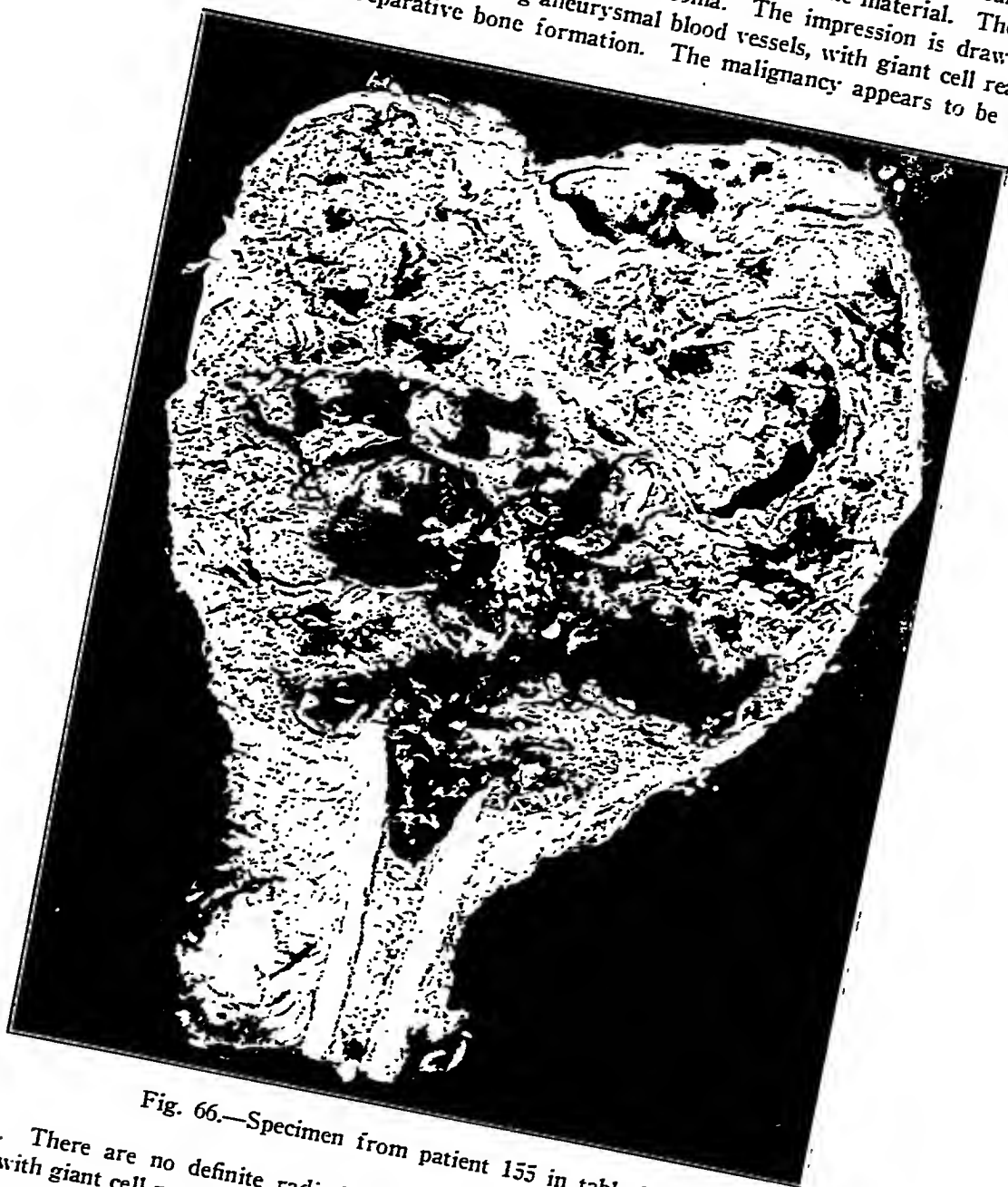


Fig. 66.—Specimen from patient 155 in table 7.

erate. There are no definite radiation changes. The diagnosis is aneurysm of bone with giant cell reaction."

From the roentgen-ray and clinical data, this case was regarded as a typical giant cell sarcoma, but the microscopic examination showed it to be probably a central malignant tumor. July 28, 1925, the patient was alive but in poor health: there was no evidence of lung metastases. The patient was living, November, 1926, with no evidence of metastases.

to be the result of stimulation of the epiphyses by the syphilitic osteo-periostitis, being analogous to the increase in length of the shaft in other diseases that occur during the period of growth.

CASE 2.—A white American boy, aged 13 years, was admitted to the hospital in August, 1925, with the complaint of awkwardness and lack of sex development. During the previous three years he had failed in his school work; prior to this he had been quite apt and had made his grades. Two years before admission, he fell a distance of 30 feet and sustained a compound fracture of the left forearm. He was treated at the Cleveland City Hospital, where the history of scaling of



Fig. 1 (case 1).—Right tibia and fibula showing operative defect in tibia.

the palms and soles was obtained; the blood examination showed a four plus Wassermann reaction. The fractured radius and ulnar healed satisfactorily within six weeks, after which he was given antisyphilitic treatment regularly over a period of six months. The past history was unimportant, while the family history revealed that the parents were syphilitic.

The results of the physical examination were unimportant except for the observation of a few scattered, enlarged lymph glands in the posterior cervical region and a convergent strabismus of the right eye. The right lower leg showed some anterior thickening over the tibia. The right tibia measured, from the

a window shade, the patient fell, striking her hip on the sharp edge of a piece of furniture. In the winter of 1921, she noticed numbness in both feet and began to limp, being obliged to use a cane; she was treated for rheumatism. The condition grew worse during the winter of 1920; in January, 1921, she was treated at the New York Neurological Institute; no roentgenograms were taken. Later she went to the New York Hospital for Deformities and Joint Diseases, where



Fig. 67 (case 156 in table 7).—Periosteal sarcoma of tibia with metastases in lungs, showing remarkable control of primary and secondary growth by roentgen-ray treatment, April, 1926, disease steadily progressing and condition hopeless.

a roentgenogram was taken and a diagnosis of tumor of the femur was made. She went to the Memorial Hospital in February, but her condition was regarded as hopeless and no treatment was advised. In March, 1921, she was referred to Mount Sinai Hospital and was placed under the care of Drs. Howard Lilienthal and H. Neuhof.

Physical examination showed a girl of definitely retarded mentality. The eyes presented an internal strabismus; the teeth were soft and the incisors showed notching. The chest was asymmetrical, with prominence of the sternum of the pigeon breast type and a left dorsal right lumbar scoliosis with rotation. The heart and abdomen were normal.

The lower part of the left leg (figs. 3 and 4) appeared much larger than the right, with a marked redundancy of the subcutaneous tissues extending from the knee to the toes. The subcutaneous tissue was soft and flabby and seemed to be differentiated from the muscle planes; the skin was thrown into folds along the outer border of the foot. There was definite increase in the size and number of the veins over the inner aspect of the lower part of the left leg. An irregular, brownish, nonelevated area of pigmentation extended from the groin to the internal aspect of the ankle. Motor function of all the muscles of the lower part



Fig. 3 (case 3).—Elephantoid enlargement of the lower part of the left leg, with tilting of pelvis.

of the leg was markedly diminished, with anterior bowing in the lower third of the tibia. The pulsation of the left dorsalis pedis artery was equal in force and volume to that of the right. The reflexes and sensation were normal.

The measurement of the left tibia from the internal joint space to the malleolus was 3.5 cm. greater than the right. The thighs were equal in size. The circumference of the right knee was 29 cm.; the left knee, 29 cm.; the left calf, 27 cm.; the right calf, 25 cm.; the right ankle, 20 cm.; the left ankle, 28 cm.; the left foot at the scaphoid, 21 cm., and the right foot at the scaphoid, 19.5 cm.

The blood Wassermann reaction was negative on two examinations. The hemoglobin content was 90 (Tallqvist); the white blood cells totaled 8,400. The urine was normal.

The roentgenograms (fig. 5) gave evidence of the increased lengthening of the left tibia and thickening of the anterior cortex similar to that seen in syphilis.

While the following is not strictly speaking a long bone case, in view of the recent interest displayed in this type of case we have thought it worthy of brief mention here:<sup>24</sup>

CASE 49.—*Endothelioma or endothelial myeloma of the os calcis.*

C. T., a boy, aged 9 years, was admitted to the Memorial Hospital under the care of Dr. James Ewing, Oct. 3, 1923. In October, 1922, the patient felt a severe pain in the left heel which lasted for three days and then disappeared. Three months later it returned and again disappeared. In March, 1923, he had another attack of pain in the same locality immediately followed by the appearance of

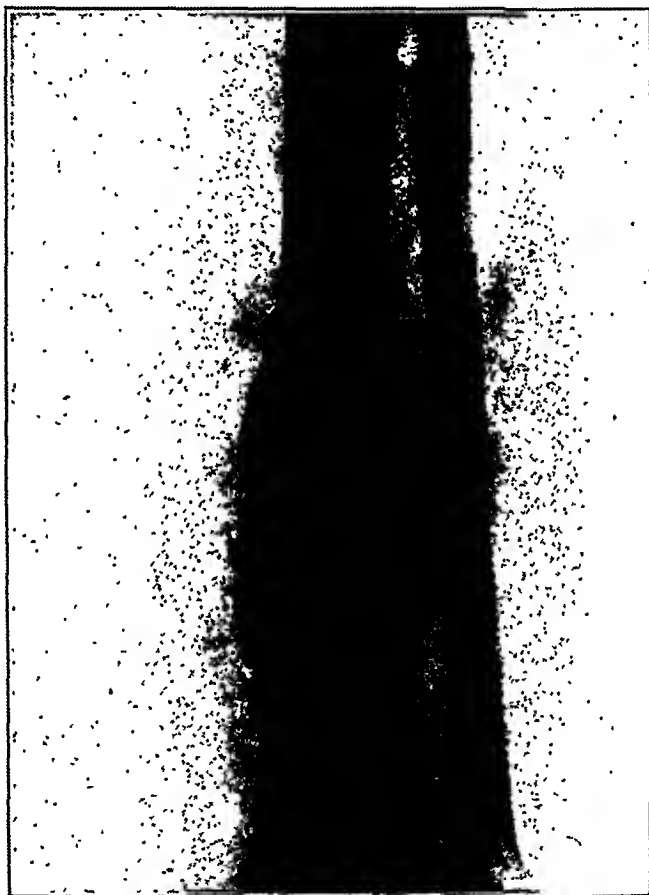


Fig. 68.—Osteomyelitis following trauma closely simulating sarcoma.

a diffuse swelling. In September, 1923, he was operated on by Dr. J. F. Thompson of Galveston, Texas, who removed the entire tumor which was found to involve a portion of the os calcis. A section was sent to Dr. Ewing for microscopic examination, and he pronounced it an endothelial myeloma. Roentgen-ray examination at the time of the patient's entrance to the Memorial Hospital showed an osteomyelitis with no new bone formation. Roentgenograms of the chest were negative.

24. This patient was under the care of Dr. James Ewing and we are indebted to him for the history and illustrations. The case is of unusual interest because it showed the most widespread generalization that we have ever observed.



foregoing except that the tumor tissue lay entirely below the fascial plane, with definite encapsulation.

This disturbance, although commonly spoken of as a congenital hypertrophy, can hardly be such since none of the cases show an increased growth of normal tissue alone, which is seen in the rather more common hemihypertrophies, a number of which have been reported.

Jordan has distinguished two types of enlargement, or elephantiasis: a diffuse neurofibromatosis involving in one type the nerves; in the other, the cutaneous structures and muscle tissue. He believes that the blood vessels give origin to the new tissue. My case would perhaps fall within the latter classification.



Fig. 5 (case 3).—Subcutaneous tissue; the fibrosis and numerous small lymph channels should be noted.

Telford's<sup>5</sup> case, although one of hemihypertrophy, presented several features in common with this one, viz., nevus, enlarged veins and overgrowth of subcutaneous tissue. He states that the association of localized hypertrophy with nevus and varices, though rare, appears to form a definite clinical entity. The disease when fully developed presents three features, of which the nevus is congenital but more apparent as growth develops, while the varices appear later, and in some instances of the disease are small or entirely lacking.

The limitation of these factors, viz., hypertrophy, nevus and varices, to one extremity is uncommon while unilateral involvement was recognized as early as 1858 by J. Adams, who reported a case in the *Lancet* of that year. The first important reference is the research of Trelat

5. Telford, E. D.: Hemihypertrophy of the Body with Nevus and Varicose Veins, *Lancet* 2:1291, 1912.

February, 1917, she had a similar attack of pain in the same shoulder, extending over the pectoral muscles and around the clavicle and scapula; there was no fever. One week later, there was diminished resonance at the base of the left lung; this was thought to be a pleural effusion; there did not seem to be any acute pleurisy. On the following day, the temperature rose to 100 F. and there was a distinct effusion at the base of the left lung. This cleared up in a few days and the patient was taken to Bryn Mawr Hospital for a roentgenogram of the chest.

Roentgen-ray examination showed in front of the apex of the left lung extending outward, from the vertebral column, a distinct tumor shadow which was nonpulsating and involved the first rib. There was a slight vocal fremitus increase at the apex of the lung.

The patient consulted Dr. Gibbon, who made a diagnosis of inoperable sarcoma of the first rib; this diagnosis was confirmed by Drs. James Alexander Miller and Douglas Quick of New York, who also examined the patient. She was admitted to the Memorial Hospital, March 26, at which time, physical examination showed a tumor of the first rib about 3 inches (7.6 cm.) in diameter. Roentgen-ray examination by Dr. Quick showed "a rarefaction and destruction of the posterior half of the first rib on the left side. Associated with and apparently attached to this was a tumor mass which filled up the left apex and extended a half inch below the level of the clavicle anteriorly. This mass was encapsulated below; the clavicle was normal throughout; the glands were enlarged; there were râles in both lungs. The roentgen-ray diagnosis was periosteal sarcoma of the first rib of the left side with an attached tumor of the left apex and metastases in the lung roots."

From March, 1917, to March, 1918, she received a total of 17,680 millicurie hours of radium. The mixed toxins were begun, April 1, dose of one-fourth minim, and steadily increased during the next two months up to 8 minims; this dose produced a chill and temperature of 103 F. The injections were kept up at home for nearly a year. The patient made a complete recovery, and is well at the present time, with no evidence of a recurrence, more than eight years later. Roentgenograms of the chest were taken every year for a number of years; the last one, taken in 1926, showed that the tumor had almost entirely disappeared. The patient is in good health in July, 1926, nine years later.

*CASE 52.—Sarcoma of seventh and eighth ribs; disease controlled by roentgen ray and toxins.*

Mrs. J. D. F., a woman, aged 28, with a negative family history, fell downstairs in 1908; no pain followed. Since 1915 she felt pain in the right side of the chest; there was never anything palpable externally. In 1919 she consulted Dr. Jerome B. Cook of St. Louis, who had a fluoroscopic examination made; this proved negative. In May, 1922, she felt pain just below the right breast, radiating through to the back; this was worse at night. Dr. Cook had some roentgenograms made which showed a tumor about 3 inches (7.6 cm.) in diameter, involving the seventh and eighth ribs, chiefly the latter, situated about 2 inches (5 cm.) from the median line. There was apparently a pathologic fracture.

An exploratory operation was performed by Dr. Cook in June, 1922. A piece of tissue was removed and pronounced, by Dr. S. E. Newman, a round and spindle cell sarcoma. This microscopic diagnosis was confirmed by Dr. James Ewing.

A roentgen-ray examination was made by Dr. P. S. Schnobelen of the Jewish Hospital of St. Louis, October 10; his report was: "This skiagraph shows a

# THIRTY-FIRST REPORT OF PROGRESS IN ORTHOPEDIC SURGERY \*

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ROBERT SOUTTER, M.D.; HARRY C. LOW, M.D.  
MURRAY S. DANFORTH, M.D.  
LLOYD T. BROWN, M.D.

AND

M. N. SMITH-PETERSEN, M.D.

BOSTON

## CONGENITAL CONDITIONS

*Treatment of Old Congenital Dislocation of Hip.*—Abbott<sup>1</sup> observes that owing to the marked pathologic changes that have taken place in the joint in old congenital dislocation of the hip, reduction by the usual methods is difficult. Skeletal traction is effective in stretching the contracture of soft parts and bringing the head to the level of the acetabulum. Reduction can then be secured by operation. In a series of five successful reductions, the functional result, judged from the standpoint of stability, increased length of limb and improvement in gait, was best in the cases in which bony ankylosis in good position for weight-bearing resulted.

*Congenital Dislocation of the Hip: A Method of Determining the Degree of Antetorsion of the Femoral Neck.*—Stewart and Karshner<sup>2</sup> suggest that the degree of antetorsion of the neck of the femur can be measured by a means of the fluoroscope and goniometer. The child is placed face down, flat, on the fluoroscopic table. The angle of outward rotation which is necessary to bring the shadow of the neck into alignment with the shadow of the shaft is measured. This angle is subtracted from 90 degrees, giving an angle which represents the antetorsion of the neck of the femur.

*Congenital Dislocation of Hip.*—Putti,<sup>3</sup> before the Clinical Congress of Surgeons, reported from his records that up to the year 1924, in 1,879 cases, with a total of 2,556 dislocations, heredity seems to play a part in 13 per cent, with a familial factor in 10 per cent. Of these cases,

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\* This Report of Progress is based on a review of 230 articles selected from 595 titles dealing with orthopedic surgery appearing in medical literature between March 13 and July 24, 1926. Only the articles that seem to represent progress have been selected for note and comment.

1. Abbott, L. C.: Arch. Surg. **12**:983 (May) 1926.

2. Stewart, S. F., and Karshner, R. G.: Am. J. Roentgenol, **15**:258 (March) 1926.

3. Putti, V.: Surg. Gynec. Obst. **42**:449 (April) 1926.

CASE 54.—*Endothelial myeloma of clavicle with metastases in cervical spine; recovery under radium treatment alone; patient well four years; died in June, 1925 (cause of death not definitely known, possibly due to metastases); (case 196, Bone Sarcoma Registry, and case 5, Conner [Endothelial Myeloma, Ewing, Arch. Surg. 12:789, 1926]).*

M. K., a woman, aged 30, with a negative family history, had no history of antecedent trauma. In July, 1920, she had a "stiff neck"; this was followed shortly after by a swelling in the left supraclavicular region. She had neuralgic pain in the back of the head and in both arms and hands. She was admitted to Memorial Hospital, March 21, 1921, at which time physical examination showed a swelling the size of a goose egg over the inner end of the left clavicle; it was firm in consistency, definitely circumscribed, was fixed to and apparently arose from the clavicle. There also was a diffuse swelling over the area from the third to the fifth cervical vertebrae, extending from 4 to 5 cm. to the left of the median line; there was some limitation of the motion of the neck. The clinical diagnosis was osteogenic sarcoma of the clavicle with metastases to the cervical vertebrae. Roentgen-ray examination showed evidence of a destructive process in the sternal end of the left clavicle and in the body and transverse process of the left side in the sixth cervical vertebra. The character of this process in the clavicle, from the roentgen-ray standpoint alone, closely simulated that noted in another case of endothelioma of the radius.

From March 23, 1921, to April 1, 1922, the patient received five radium pack treatments applied at 6 cm. distance, a total of 34,050 millicurie hours. She had one roentgen-ray treatment, July 13, 1923. She remained well for four years. June 20, 1925, after about a week's illness, the patient died; the cause of her death is not definitely known; possibly it was due to metastases. The physician who attended her during the last week stated that she complained of severe headache, had a rapid pulse (140), a temperature of only 100, suffered from nausea and vomiting, and held her head to one side. Her family physician, Dr. F. Holden, stated that she died of cerebral meningitis induced by making a visit to the hospital on a hot day. It was impossible to ascertain her physical condition for a few months prior to this attack.

Dr. James Ewing's microscopic report on the specimen removed at biopsy was: "The tissue is composed of closely packed cells without uniform stroma. The cells are small, round or polyhedral; they show features of endothelial cells, but are not typical of endothelioma. It may be myeloma or endothelioma."

The remaining cases will be found in the accompanying tables.

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a chronic osteomyelitis adjacent to an epiphysis without actual invasion of the epiphysis itself. This differentiation is most important since it is my impression that even an invasion of the epiphysis by an avirulent organism or the infliction of a minimum of trauma will always retard rather than accentuate cell proliferation.

Proof of this is well illustrated in the following experiment:

One cubic millimeter of a washed staphylococcus culture of a known low virulence<sup>2</sup> and a bacterial count of 5 per high power field was injected into a 3 months' old dog. The wound healed without suppuration. The animal was followed for six months, roentgenograms being taken at intervals. There was moderate atrophy of the bones of the entire right leg with rarefaction throughout the entire lateral half of the epiphysis, and at the end of six months the femur showed 2.3 cm. shortening. There was no compensatory lengthening of the fibula on the same extremity.

When, however, infection involves the shaft of the bone with extension to the metaphyseal portion without invasion of the epiphyses itself and the necrosis is a slow progressive affair, lengthening of the part sometimes occurs.

Ollier reports a central osteitis of the tibia in a child with a dormant necrosis of the bone which induced 6 cm. lengthening of the shaft.

CASE 1.—A white girl, aged 14, received a slight abrasion of the left lower leg four years before admission; shortly afterward pain and swelling developed over the midtibia with fever. The tibia was incised and drained, and the wound healed after a period of several weeks. One year later the wound broke down, and it discharged for the following two years. The patient treated herself by changing dressings. One year before this examination, she entered the Lakeside Hospital because of pain and tenderness over the mesial aspect of the lower part of the left thigh and a discharging sinus on the internal upper portion of the lower part of the leg. There was swelling around the knee with ballottment of the patella. Saucerization of the infected area of the upper part of the tibia and lower portion of the femur resulted in an early relief of signs and symptoms. On final admission to the dispensary, the patient's general condition was excellent. Physical examination showed multiple healed linear scars above and below the left knee and normal range of motion. There was an increase of 2.5 cm. in length of the left tibia, measured from the internal joint space to the malleolus, with moderate relaxation of the joint capsule, as evidenced by an increase of 20 degrees in lateral mobility. The femora were equal in length.

The roentgenograms (fig. 1) showed the tibial and femoral epiphysial structures to be normal. There was an operative defect on the anterior upper third of the left tibia with perhaps some thickening of the posterior ostium beneath this area.

Congenital syphilis occasionally produces a rather unusual manifestation of bone growth disturbance whereby the bones of one extremity show a symmetrical overgrowth. Wilhelm<sup>3</sup> believes this overgrowth

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2. The dog has a high immunity to staphylococcus.

3. Wilhelm, S. F.: Ostitis Fibrosa and Hyperostotic Form of Bone Syphilis. Surg. Gynec. Obst. 41:624 (Nov.) 1925.

scaphoid bone to establish the bone-block back of the tibia on the os calcis. Two patients have had a secondary operation for repair of the bone block, which had fractured after a few months of functional use.

*Operation for Dangle-Foot.*—Morison and MacKenzie<sup>10</sup> report three cases of dangle-foot in which operations were performed three years previously. The operation consists of making osseous ligaments by transplanting bone and periosteum between the tibia and fibula above and the astragalus and the os calcis below. The resulting fixation in the three cases has been permanent, and roentgenograms show definite bony bridges.

*Operation for Abductor Paralysis of Hip.*—Colonna<sup>11</sup> has proposed an operation which is said to be of value in cases of paralysis of the hip if the quadriceps femoris muscle is active. It is proposed to take advantage of a portion of the quadriceps femoris muscle by detaching the long head of the rectus femoris from its two origins, and freeing this portion from its bed for a few inches. This long head is then brought through the fascia lata and is placed superficially to the tensor fascia lata, after which it is inserted into the crest of the ilium or fascia covering the paralyzed gluteus medius muscle.

*Serum Treatment of Poliomyelitis.*—Etienne<sup>12</sup> treated with serum fourteen adults who had acute myelitis. He used Pettit's poliomyelitis antiserum, prepared at the Pasteur Institute in Paris. Eighty cubic centimeters of the serum was given subcutaneously. Slight movements reappeared within forty-eight hours. The patient improved by the fifth day, was able to walk by the twelfth day, and recovery was soon complete. In a subacute case with bladder disturbances and paraplegia, improvement occurred by the third day. A month later the man went back to work. In a case of extensive paraplegia with bulbar involvement, the speech improved and the patient recovered in a few days. A patient, treated with the serum two months after the onset of the disease, began to walk in six days. Similar results were obtained in a case of eleven weeks' standing when treatment was begun. A dose of 300 cc. may sometimes be needed. In cases with prolonged course and successive involvement of the spinal cord, medulla and brain, a total of 2,200 cc. of the serum was required. In recent cases, 100 cc. of the antiserum is the usual dose given by intraspinal injection.

10. Morison, R., and Mackenzie, W.: Surg. Gynec. Obst. 42:270 (Feb.) 1926.

11. Colonna, P. C.: J. M. Soc. New Jersey 23:177 (April) 1926.

12. Etienne, G.: Médecine 7:349 (Feb.) 1926.

internal joint space to the malleolus, 3 cm. longer than its neighbor, with 1 cm. increase in the circumference of the left calf. The reflexes were normal. The blood and spinal fluid were strongly positive. The urine was normal.

The roentgenograms (fig. 2) of the right tibia and fibula presented a uniform enlargement both in circumference and in length; the epiphyses showed no abnormal change.

The most interesting and at the same time a more unusual type of overgrowth of a long bone occurs coincident with nevus and elephantoid subcutaneous tissue. Congenital hemihypertrophy of the body is not uncommon and many cases have been reported, particularly in the French literature, but hypertrophy of a single extremity has been reported in only a few instances.



Fig. 2 (case 2).—Right and left tibia and fibula, showing contrast in length and size.

CASE 3.—An Italian girl, aged 12 years, was admitted to the Lakeside Hospital, March 20, 1926, with the complaint of swelling of the left leg and foot. She was the fifth child, born at term following a normal labor. At the age of 2 years she had scarlet fever, at 5 measles, at 6 pertussis, and at 8 pneumonia. She did not walk until 3 years of age. The family history was unimportant.

A few days after birth a brownish pigmentation was noted on the inner side of the left leg, and the mother thought that the lower part of the leg and the foot were somewhat enlarged. This enlargement of the leg had steadily increased until the present time, although there had never been any restriction of activity, or pain.



## NEOPLASMS

*Endothelial Myeloma: Fifty-Four Cases.*—Connor<sup>15</sup> finds that there have been sixty-seven cases of Ewing's tumor, designated in this article as endothelial myeloma, recorded in the Registry of Bone Sarcoma of the American College of Surgeons. These constitute about 10 per cent of all cases of bone tumors registered and are reported in full. The belief that these form an entity separable from osteogenic sarcoma is borne out by the characteristics emphasized here, namely, their almost constant location in the shafts of the long bones and in the flat bones where osteogenic sarcoma seldom occurs; their peculiar morphology (the type of cell being easily distinguished from the osteoblast in most cases), and their susceptibility to radium and roentgen-ray treatment. These myelomas occur mainly in children, and many of them are preceded by trauma and by signs of inflammation. Histologically, they may be divided into the angiomatous, the reticular and the diffuse. Their development is slow, with intermittent pain and swelling; they may recede only to return and become progressive. As a final distinguishing point, the therapeutic radium or roentgen-ray test is advocated. This form of tumor, in contrast to osteogenetic sarcoma, usually disappears under the influence of these forces. Connor does not agree with the opinion of Ewing and others that endothelial myeloma arises as a solitary tumor. He believes that the multiple tumors are actual metastases. For this reason, he believes that amputation in the early stages is a form of treatment which should be considered, although apparently radium has cured the condition in several cases. The prognosis, with a combination of surgical intervention and irradiation, is not always death. Patients have lived for five years or longer after treatment.

*Angio-Endothelioma of the Bone.*—Kolodny<sup>16</sup> analyzes two cases which he believes show that angio-endothelioma of the bone is a true pathologic entity, which, however, is exceedingly rare. The diagnosis of endothelioma of the bone should be made only when all the evidence is clear and conclusive; otherwise, the diagnosis of endothelioma will continue to be the graveyard of those uncommon complex tumors concerning which present knowledge is extremely meager.

*Bone Formation in Osteogenetic Sarcoma.*—Eising<sup>17</sup> has reached the conclusions (1) that sarcoma in the bone is a malignancy of the softer structures and connective tissues in bone, progressing in the matrix and along the pathway of the haversian canals and blood vessels, and (2) that the new bone proliferation in osteogenic sarcoma is a

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15. Connor, C. L.: Arch. Surg. 12:789 (April) 1926.

16. Kolodny, Anatole: Arch. Surg. 12:854 (April) 1926.

17. Eising, E. H.: Arch. Surg. 12:867 (April) 1926.

The epiphysial lines of the left tibia were distinctly less clear cut than those of the right. The spine showed an irregular fusion of the fourth and fifth dorsal segments. In view of the increased lengthening of the tibia and the redundancy of the subcutaneous tissue, the child was operated on, March 30, 1926.

At operation dense, resistant, fibrous subcutaneous tissue was encountered which cut with some difficulty; there were a moderate number of rather large venous spaces throughout the tissue. There was no involvement of the muscles or fascia. The periosteum over the anterior surface was rather irregular and stripped with difficulty. A piece of subcutaneous tissue was removed for histologic examination. The tibia was shortened 2 cm., with anticipation that the soft tissue might be resected at a second stage. However, on the third day after operation the patient developed a pulmonary complication, and examination of the sputum showed tubercle bacilli. The physical signs cleared up rather rapidly,



Fig. 4 (case 3).—Anterior cortex of left tibia, showing thickening with elongation.

and she was discharged three weeks after operation. Union of the tibia was firm at the end of eight weeks. It was thought wise in view of the pulmonary disturbance to delay resection of the soft tissue until a later date.

The histologic examination, as reported by Dr. H. T. Karsner, showed considerable fibrous tissue loosely arranged. A few pieces of bone were present in the tissue, together with a few small lymph and venous spaces (fig. 6). The trabeculae of the bone were thicker and closer together than normal, with narrowing of the haversian canals.

Campbell<sup>4</sup> has recently reviewed the literature of congenital hypertrophy and reported a case which was clinically almost similar to the

4. Campbell, W. C.: Congenital Hypertrophy, *Surg. Gynec. Obst.* 36:699 (May) 1923.

tions of hypertonic salt solution have been used in the treatment in sixty-six cases of thrombo-angiitis obliterans. Improvement has resulted in the majority of patients, cessation of pain, increased temperature of the extremity, growth of the nails, healing of the ulcers and the reopening of obliterated vessels. No dangerous reactions or untoward results of any kind have been noted in more than 2,500 injections. Four consecutive successful amputations below the knee have been performed in four advanced cases after preliminary treatment with physiologic sodium chloride solution. If begun before the disease is too far advanced, treatment of thrombo-angiitis obliterans by repeated injections of hypertonic sodium chloride solution will check the progress of the disease and will restore the patient to health and usefulness in the majority of instances.

#### ARTHRITIS

*Pathology and Treatment of Chronic Arthritis.*—Pemberton<sup>22</sup> bases his discussion of the pathology and treatment of chronic arthritis on a critical consideration of 1,200 cases. Although treatment of the disease is in the realm of internal medicine, he believes it has received more profitable attention from orthopedic surgeons than from any other group. So much emphasis has been placed on focal infections that the idea has gained ground that treatment in this disease may be successful if the patient is treated by dental, aural, laryngologic or gastro-intestinal specialists. This conception, he points out, is far from adequate, and is responsible for many of the failures to relieve the symptoms. The 400 army cases which he studied carefully provide important data. Forty-six per cent of the patients recovered in the presence of demonstrable foci; 16 per cent recovered after the removal of foci. This significant observation suggests that there are other factors than mere focal infection which play a large rôle in the determination of invalidism or recovery. Twenty per cent of the patients showed a somewhat lowered basal metabolism. The urea and nonprotein nitrogen content of the blood were normal in all the uncomplicated cases, and on many grounds it can be stated with confidence that there is no justification for the old practice of denying these patients the so-called "red" meats. The anemia incidental to arthritis may be aggravated by this unnecessary prohibition. Even after the removal of possibly causative foci, a more or less permanent physiologic change, adequate to perpetuate symptoms, may remain for a long time. Arthritis is only one branch of a large tree, and merely constitutes the surface expression of an underlying pathologic condition. The author considers nearly every case of arthritis which presents serious deformity a reproach to the medical profession, and he

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22. Pemberton, R.: W. Virginia M. J. 22:232 (May) 1926.

and Monod,<sup>6</sup> "Asymmetry of the Body," which appeared in 1869; this was followed by articles by Leblanc<sup>7</sup> (1898) and Duplay<sup>8</sup> (1898), and by a remarkably complete article by Kluppel and Trenaunay (1900). Guinaud took the disease as the subject of a Paris thesis in 1901.

Overgrowth of the bone usually predominates although any tissue in the involved area may be hypertrophied. The origin of the disease is in an antenatal pathologic condition. Ewing,<sup>9</sup> quoting from various authors, considers this disease to be a type of cutaneous fibroma, concerned with many complex factors, most of which center in the nervous system.

#### SUMMARY

Overgrowth of the tibia and fibula in three patients between the ages of 12 and 14 seemed to result from entirely different etiologic factors. The first patient showed an increase in length due to stimulation of the cartilaginous cells of the epiphysial plate from adjacent osteomyelitis without invasion of the epiphysis. The second patient had a history suggesting congenital syphilis without manifestations other than a positive blood Wassermann reaction. The third patient showed a generalized enlargement of the lower part of the left leg, with nevus and enlarged veins apparently of congenital origin.

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6. Trelat, V., and Monod, A.: *De l'hypertrophie Unilateral Partielle ou totale du corps*, Arch. gén. de méd. 10:257-278, 1888.

7. Leblanc, E.: *Contributions à l'étude de l'hypertrophie congenitale unilaterale partielle ou complète: Du rôle probable de la métamérie Embryonnaire dans son evolution pathogénique*, Paris, 1897.

8. Duplay: *Hemihypertrophie partielle*, Gaz. hebd. de méd. 2:529-532, 1897.

9. Ewing, James: *Neoplastic Diseases*, Philadelphia, W. B. Saunders Company.

results of ramisection have been almost universally disappointing. In discussing treatment, he agrees with Bankart that massage is of no value. The purpose of all operative treatment is to remove excessive muscle spasm in certain groups, thereby correcting deformity and restoring muscle balance. Operative procedures may be undertaken when the patient is 3 years of age, and he considers that only two types of operation are worth discussing: (1) operations on the tendons and muscles and (2) operations on some of the motor nerve fibers passing to the spastic muscles. The first group of tendon operations includes tendon lengthenings, myotomies and tendon transplantations; the second, Stoffel's operation on the afferent fibers on the basis of the anatomy of the peripheral nerve bundles. His estimation of the relative value of these two types of operation is as follows: After an extensive trial and a review of the results of sixty operations on the internal popliteal nerve, he concludes that for the relief of equinus the nerve operation possesses no advantages over lengthening of the Achilles tendon by open operation. In cases of obstinate knee flexion, he considers that the excision of the appropriate fibers of the sciatic nerve running to the long head of the biceps and the semimembranosus and a portion of the fibers running to the semitendinosus gives better results than operations on the hamstring tendons. He also believes that better results follow excisions of the obturator nerves in cases of severe adduction of the thighs than radical muscle or tendon operations. He attacks the nerves by an abdominal extraperitoneal route. He overcomes severe internal rotations by an attack on the superior gluteal nerve, excising only its terminal portion near the trochanter. He controls severe pronation in the arm by excising some of the fibers of the median nerve running to the pronator radii teres, the flexor carpi radialis and the palmaris. He calls attention to the importance of using a battery to pick out the appropriate fibers, since the arrangement of the bundles of the median nerve has not in his experience been constant. For after-treatment he depends on night retentive apparatus, the usual braces and muscle training. He has noticed that keloid is prone to occur in these cases.

*Physiology of the Sympathetic Nervous System in Relation to Ramisection.*—Forbes and Cobb<sup>26</sup> doubt whether any success that may follow the operation of ramisection in cases of spastic paraplegia can be ascribed to the operation itself. Many factors may enter into the success of such an operation. In addition to the actual effect of interrupting the sympathetic nerve path, there are other possible causes of improvement, such as exercises, mental suggestion, hospital care and nursing. Some operations have been entirely unsuccessful. The proposal to relieve

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26. Forbes, Alexander, and Cobb, Stanley: J. A. M. A. 86:1884 (June 19) 1926.

the deformity occurred in 84.9 per cent females and in 15.1 per cent males. Sixty per cent of the dislocations were single, and 39 per cent were double. Geographically, in Italy it was frequent in the northern provinces, rare in the south and almost unknown in Sicily. The dislocation can result from a number of factors, of which the mechanical is without doubt the most frequent, if not the only cause. The earliest possible diagnosis, even before the child begins to walk, is of great importance. If the dislocation is unilateral, the cutaneous creases of the thigh evident in the infant are not symmetrical, and are displaced proximally on the dislocated side; the inguinal and gluteal pleats are deeper and longer than on the normal side. The outline of the dislocated hip is more prominent. The luxated limb has a tendency toward external rotation. Abduction is slightly diminished. Shortening is nearly always minimal, but appreciable. If the dislocation is bilateral, there is no difference in length of limb, but the pelvis appears enlarged because of the projection of the trochanters, the buttocks are flattened, and the limbs may not be normally abducted. Putti's experience has led him to be conservative in treatment, the bloodless method being used in all cases except those in which the reduction cannot be obtained in this way. This occurs in 5 per cent of the cases. The results in 700 cases in which treatment was given in the year 1923 show functional and anatomic success in about 80 per cent in the single and in 60 per cent in the double dislocations. On the basis of 1,879 cases with 2,556 dislocations, the results were successful in 90 per cent of the single and 65 per cent of the double cases. Anterior transposition, particularly in bilateral cases, may sometimes produce results functionally as satisfactory as those which are anatomically perfect. Putti believes that the treatment will be more successful when it becomes generally possible to begin treatment at an earlier age than is now the case.

*Treatment of Congenital Dislocation of the Hips by Early Mobilization.*—Up to 4 or 5 years of age, Ducroquet<sup>4</sup> has found that the results of reduction are remarkably successful. He treated 300 patients successfully, but later the reduction offered great difficulties. It is only in children under 5 years of age that a new joint cavity is easily formed. The retraction of the ligaments is greater as the child grows and causes an increasing obstacle to reduction. There are two opposing factors, the difficulty and slowness of forming a new cavity and the early and firm retraction of the ligaments. To obviate the development of joint stiffness, active motion should be employed, retaining the stability of reduction intact. The technic is as follows: After reduction is obtained, the thigh is covered on its anterior surface by large pieces of cotton. This cotton is cut in triangular form with the base at the level of the knee, a

4. Ducroquet, R.: Arch. franco-belges de chir. 28:1030 (Dec.) 1925.

advanced by antisyphilitic treatment, syphilis may be considered as a factor in the etiology of the author's case. He goes on to say that a toxic or infectious factor, may, perhaps, cause this congenital infection, acting on the amniotic sac between the fourth and sixth week of fetal development, but that it probably is the syphilitic infection which is more often present and, therefore, that this should always be sought carefully.

*Chondrodysplasia.*—Cole<sup>30</sup> reports one case of chondrodysplasia and reviews the literature on the subject. He believes that the term "Ollier's disease" is one which is fixed in the literature, but which should be used only to designate the cases of cartilaginous dystrophy with or without cartilaginous tumor formation which show an asymmetrical involvement of the body as the outstanding clinical feature. Chondrodysplasia (a term preferable to dyschondroplasia) is a condition that is usually asymmetrical; but as several symmetrical cases are on record, the term must be broader in its application than as used by Ollier in describing "Ollier's disease."

#### RICKETS AND METABOLIC DISTURBANCES

*The New Haven Demonstration of Community Control of Rickets.*—Eliot<sup>31</sup> believes that antirachitic treatment should be begun in the first month of life and continued faithfully for two years. In the temperate zone, rickets is nearly a universal disease among infants, whether breast or artificially fed. The New Haven demonstration was undertaken to show that 90 per cent of the infants seen by roentgen-ray examination showed evidences of slight rickets before they were 6 months of age. When the directions regarding cod liver oil and sun baths were followed regularly, these infants did not develop the slightest evidence of rickets; that is, the disease was controlled. In contrast to this group stands the control series, which showed 18 per cent of moderate or marked rickets at 10 months, 25 per cent at 13 months and 37 per cent at 25 months of age.

*Permanent Rickets: Eight Cases.*—Hess<sup>32</sup> concludes that recurrences of rickets are frequent, especially during the second year of life. Hence, specific therapy, whether cod liver oil or ultraviolet irradiation, should be continued after all signs and symptoms of rickets have disappeared. Furthermore, cod liver oil should be given not only during the first but also during the second winter. This is advisable, particularly in regard to infants who have had rickets and are therefore susceptible to a recurrence.

30. Cole, W. H.: Surg. Gynec. Obst. 42:359 (March) 1926.

31. Eliot, M. M.: Pub. Health J. 17:114 (March) 1926.

32. Hess, A. F.: Am. J. Dis. Child. 31:380 (March) 1926.

reflexes are normal, the patient is allowed to be up. This result will be obtained in two years from the beginning of the cure. Patients with a closed spondylitis may expect without exception a certain cure by this treatment, but the prognosis in cases with mixed infection is much more unfavorable. Rollier is a determined opponent to the use of plaster apparatus. He advises corsets of celluloid, freely perforated, or linen reinforced with steel. These are made from plaster casts, and should be worn for a year. After cure, the patient should continue his sun baths at home.

*Nonspecific Cold Abscesses.*—Melchior<sup>7</sup> states that genuine tuberculous abscesses frequently have all the characteristics of hot abscesses. On the other hand, one frequently finds cold abscesses of nontuberculous nature. Such cases are found following osteomyelitis, typhoid fever, bullet wounds or wounds caused by other foreign bodies; likewise, in empyema of the gallbladder, abscesses of the sweat glands or lymphadenitis. He reports four cases of multiple abscesses with typical signs of cold abscess, showing staphylococci exclusively. The granulation tissue revealed no traces of tuberculosis on microscopic study.

*Rheumatism of Tuberculous Nature.*—Harvier<sup>8</sup> reports a case of rheumatism of tuberculous origin in a patient, aged 40, who developed chronic rheumatism after three acute attacks, twenty-three, four and three years before, respectively. Roentgenograms demonstrated lesions of the joints and bones. Repeated bronchitis and anal fistula were among the signs suggesting the diagnosis of tuberculosis. Inoculation of guinea-pigs with the effusion from the knee joint proved that the fluid contained tubercle bacilli.

[ED. NOTE.—Why call this rheumatism? Ely and Rollier present two diametrically opposed points of view. We cannot agree with Ely that operation is the only cure for Pott's disease, nor do we agree that operation should be performed in the presence of multiple infection. We also feel strongly that children should be treated conservatively. Again, Ely's after-care, six months, seems perhaps to explain why only twenty-eight of fifty-three patients were benefited. Rollier, on the other hand, has the enthusiasm of a propagandist for a special type of so-called cure.]

#### POLIOMYELITIS

*The Surgical Treatment of Dangle-Foot.*—Ollerenshaw<sup>9</sup> has operated in nineteen cases of drop-foot by the "bone-stop" method of Campbell. He uses the bone removed from the subastragaloid joint and

7. Melchior, E.: Beitr. z. klin. Chir. 133:205, 1925.

8. Harvier, P.: Bull. et mém. Soc. méd. d. hôp. de Paris 50:509 (March 26) 1926.

9. Ollerenshaw, R.: Brit. M. J. 1:525 (March 20) 1926.



*Osteomalacia in Kashmir.*—Vaughan<sup>36</sup> says that osteomalacia is common in Kashmir. Almost all Kashmiri women who have borne children are affected in some degree, with the exception of the boatman class. The latter women live in the open air on large freight boats, work hard and eat with the men. They are too poor to cook their food, and eat such raw vegetables as cucumbers and tomatoes with their rice. The worst cases are seen in the homes of the wealthy, who keep their women in seclusion, and among those of the poorer classes who do the same. Many deaths take place during childbirth owing to conditions consequent to osteomalacia; as skilled assistance is not available, mother and child often are lost. Rickets is not common in Kashmir.

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36. Vaughan, K.: Brit. M. J. 1:413 (March 6) 1926.

(To be continued)

## SYPHILIS.

*Roentgenologic Study of Congenital Syphilis of the Long Bones.*—Péhu, Chassard and Mme. Enselme<sup>13</sup> have studied for many years the changes in the long bones due to congenital syphilis which occur in infancy, that is, from birth up to the second year. They divide these into four groups: (1) gummas, which are rare; (2) osteomalacic changes, which represent a dystrophy of the bone, also being rare; (3) the osteochondritis of Weyner-Parrot type, which usually begins in utero about the fifth month of pregnancy, but may be delayed as late as the third month of life; (4) hyperplastic periostitis, which is by far the most frequent manifestation of congenital syphilis, comprising about 80 per cent of their cases. The condition is demonstrated only by a roentgenogram, and the bones of the four extremities are often affected in an exactly similar and symmetrical manner. These changes begin in the first three months of life, and continue until about the eighteenth. It is, therefore, an extra-uterine condition.

## PYOGENIC INFECTIONS OF BONES AND JOINTS

*The Aspiration of Septic Joints of Low Virulence.*—Lonergan<sup>14</sup> gives the details in three typical cases chosen from a large group of septic joints of low virulence observed at the Children's Hospital in Boston. In this group there usually was an initial trauma, followed in a day or two by increasing tenderness, swelling and heat in the joint. There were temperature elevation of from 1 to 4 degrees, a large number of white blood cells and a varying amount of general constitutional reaction. The treatment consisted of immediate aspiration, from which sometimes turbid fluid and sometimes thin pus was obtained. Some of the cultures showed no growth and others a staphylococcus of low virulence. The patients were carefully watched, but no other operative procedure was necessary, and a full return of motion and quick subsidence of local and constitutional symptoms followed.

[ED. NOTE.—These observations of Lonergan are of value as suggesting that in many cases of mild sepsis with joint effusion in children the simple relief of tension may enable the joint tissues successfully to combat bacterial invasion. We strongly emphasize the necessity for hospitalization and close clinical and bacteriologic observation if such a case is to be handled safely.]

13. Péhu, M.; Chassard, M., and Enselme, J.: J. de radiol. et d'électrol. 10:54 (Feb.) 1926.

14. Lonergan, R. C.: Boston M. & S. J. 194:661 (April 15) 1926.



secondary process, and is the result of an attempt at the establishment of a natural barrier to the intrusion of the neoplastic process.

*Registry of Bone Sarcoma.*—Codman<sup>18</sup> presents an excellent report of the Registry of Bone Sarcoma. It is divided into two parts: one part contains twenty-five rules for establishing the diagnosis of osteogenetic sarcoma; the other part is a report of thirteen registered cases of "five year cures" analyzed according to these criteria.

*Myxochondrosarcoma of the Knee.*—Fedeli<sup>19</sup> describes a case of myxochondrosarcoma of the capsule of the knee following trauma. He gives the differential diagnosis and reports on the microscopic appearance after amputation. In making a differential diagnosis from tuberculosis and from acute and chronic inflammatory lesions, he indicates the value of the roentgenograms, the absence of increase in local surface temperature, the retention of movement until the joint lining is involved, the changes in the overlying superficial veins and the character of the swelling.

*The Similarity of the Roentgen-Ray Observations in Multiple Myeloma and in Sporotrichosis.*—Altschul<sup>20</sup> calls attention to the possibility that the rare condition of sporotrichosis of the bones of the skull may present a roentgen-ray picture almost entirely identical with that found in multiple myeloma of the skull.

#### VASCULAR DISEASE

*Treatment of Thrombo-Angiitis Obliterans by Intravenous Injection of Hypertonic Salt Solution: Preliminary Report.*—Silbert<sup>21</sup> asserts that the etiology of this disease is not understood. No satisfactory explanation has yet been given of the peculiar distribution of the disease. Whether the abnormality is primarily one of the blood vessels, of the sympathetic nervous system or of the glands of internal secretion, is yet to be determined. Although the discovery of the real nature of the process is of great importance if a rational therapy is to be evolved, various forms of treatment are being tried. Koga, in 1913, first suggested the intravenous administration of fluids in thrombosis obliterans. At present the author uses a 5 per cent hypertonic solution of sodium chloride, 150 cc., for the first injection and 300 cc. for all subsequent injections. Immediate improvement may occur, but often there is no improvement until a few weeks later. In a series of sixty-six cases, forty-six patients have definitely improved. Repeated intravenous injec-

18. Codman, E. A.: Surg. Gynec. Obst. 42:381 (March) 1926.

19. Fedeli, F.: Chir. d. org. di movimento 10:209 (Feb.) 1926.

20. Altschul, Walter: Am. J. Roentgenol. 15:224 (March) 1926.

21. Silbert, Samuel: J. A. M. A. 86:1759 (June 5) 1926.

The iodized oils used were lipiodol (Lafay), which contains 40 per cent of iodine by weight combined with poppy seed oil; and iodipin, which contains 40 per cent by weight combined with sesame oil. Iodipin can be obtained in either 10 per cent or 40 per cent compounds. It is possible that the other oils can be used, but the two mentioned are the oils we use in our work.

It is interesting to know that the iodine is so firmly combined with the oil that the iodine reaction cannot be obtained in patients who are expectorating sputum combined with the oil. Iodized oil is not rapidly broken down in the lungs but may be in the gastro-intestinal tract, when it is swallowed, or when through accident the oil is introduced into the esophagus. Iodism may thus result.

The choice of the five methods of technic in use usually varies with the experience of those interested in the methods. Laryngologists prefer the bronchoscope; pediatricians, the tracheal trocar. Medical men and roentgenologists prefer the intratracheal injection through the mouth. No matter which method is used, approximately from 20 to 40 cc. of the oil must be used to produce suitable roentgenograms.

#### FIRST METHOD<sup>3</sup>

In the first method, the patient is placed in a horizontal position, preferably on a roentgen-ray table so that after the introduction of oil the roentgenogram can be taken immediately. It has been shown that frequently patients will cough out the oil before the roentgenogram is taken; then the whole operation must be repeated.

The head is placed in hyperextension in order to locate the cartilages more easily. The skin is prepared by the application of tincture of iodine and the operator places himself on the right of the patient, immobilizing the thyroid cartilage between the thumb and the second finger of the left hand, while with the index finger he palpates the cricothyroid membrane. He then rapidly anesthetizes the skin and subcutaneous layers of tissue with procaine hydrochloride, and guided by the left index finger, which has located the correct position, the trocar is forced through the tissues in a plane perpendicular to the larynx. Following this, by movement upward of the plate at the base, the trocar is pushed farther into the trachea, and at the same time becomes parallel with its walls, while the plate rests flat against the neck. When the stilet is withdrawn, a whistling sound of the inspired air denotes a correct position. The syringe containing 5 cc. of procaine hydrochloride is now attached, the head of the patient is slightly withdrawn from its extreme hyperextension in order to prevent the liquid from flowing toward the glottis, and slight pressure exerted to cause its entrance. A forcing out of the piston and the presence of bubbles of air caused by the cough incident to the irritation of the first few drops of the solution confirm the correct position of the trocar in the trachea. Should these indications not be present, one of course suspects a false entry or the presence of a fold of mucous membrane over the opening. A small amount of manipulation of the cannula and the use of the stilet will usually give results fairly quickly.

believes that the outlook for the arthritic patient who is treated vigorously, and above all intelligently, is growing progressively better.

[ED. NOTE.—We are in hearty accord with these conceptions of Pemberton. We should continue to remove such easily accessible foci as may play a part in lowering the patient's resistance, but we should consider arthritis as a generalized disease, of which the foci may be a symptom as well as the affected joints. If we examined apparently well persons as carefully as we examine arthritic patients, we should find many such foci, and if we succeed in overcoming the generalized disease many of these suspected foci cease to be important factors, as Pemberton's statistics prove; these may actually disappear as the patient's resistance to bacterial invasion is increased.]

*Synovectomy in Chronic Infectious Arthritis.*—Swett<sup>23</sup> believes that synovectomy is an operation that warrants further trial in carefully selected cases of chronic infectious arthritis. It may be expected to promote the restoration of function to those joints in which resolution of the exudate has been delayed. It may also prevent the further destruction of the cartilages and the secondary ankylosis which would result from the prolonged presence of large amounts of organized inflammatory exudate. It should be done before bone and cartilage changes occur, in the hope of preventing such changes. Furthermore, bone and cartilage changes do not contraindicate synovectomy, but the resulting benefit may be prejudiced by such changes and to a degree in direct proportion to their extent. These observations are based on an experience of thirty-nine synovectomies in thirty-two patients, one in the wrist, three in the elbow, thirty-two in the knee, one in the hip, one in the finger and one in the ankle.

*Calcium Content of Blood in Gout and Arthritis.*—From an analysis of the blood in cases of gout and arthritis, Horowitz<sup>24</sup> finds that the estimation of the blood calcium, except in acute gout, whether during attacks or in the intervals, is of no help in distinguishing gout from arthritis.

#### DISTURBANCES OF THE NERVOUS SYSTEM

*Treatment of Spastic Palsy in Children.*—Fairbank,<sup>25</sup> whose experience is wide, has written a valuable article on this subject. He believes that in most cases of spastic palsy the intracranial damage has been done before birth, but that enough cases of such a disease as syphilis exist to make it necessary for the surgeon to assure himself that the case is not progressive before he advises operative intervention. In the ordinary case he doubts the value of decompression, as suggested by Sharpe, and he considers that the

23. Swett, P. P.: *Am. J. Surg.* 40:49 (March) 1926.

24. Horowitz, P.: *Am. J. M. Sc.* 171:560 (April) 1926.

25. Fairbank, H. A. T.: *Brit. M. J.* 1:776 (May 1) 1926.

from danger, provided he cooperates perfectly. He must be perfectly relaxed, and have confidence in the operator. The pharynx and larynx are anesthetized with 20 per cent cocaine solution. The patient may have been placed in twilight sleep previously. He is then placed on his back with his head elevated, and slight extension is made at the occipito-atloid joint by the left hand of the first assistant. The bite-block is placed on the assistant's right thumb and inserted into the left angle of the patient's open mouth. Complete description of the methods of direct laryngoscopy will be found in Jackson's book.<sup>1</sup> With the laryngoscope in place, a catheter is introduced into the bronchus, and from 20 to 30 cc. of oil is introduced. The laryngoscope is removed, the patient is placed on the side that is diseased and the roentgenogram is taken. This method is not applicable to children or to patients who have dyspnea.

### THIRD, OR BRONCHOSCOPIC, METHOD

The third method, while more exact in locating diseased areas under direct vision, requires too great skill for general adoption. The iodized oil, 40 per cent, is warmed and injected through the bronchoscope, the bronchoscope is then withdrawn, and the patient remains in the position in which the examiner desires to place most of the iodized oil.

Jackson and his co-workers have used bronchoscopic methods for lung mapping, using a finely powdered bismuth subcarbonate. The roentgenograms taken with this substance are not quite as distinct as the ones now obtained with the iodized oil, 40 per cent. I have had a patient who has received a mixture of bismuth in oil, which later acted as a foreign body in the lungs, with a resulting obstruction to drainage. This patient had a bronchiectasis in the lower part of the right lung for which he had been treated by thoracoplasty. This did not produce the desired result, and it became necessary to perform a partial pneumectomy. The bismuth in oil obstructed the drainage of certain areas of the lung.

I do feel, however, that when it is necessary to subject a patient to bronchoscopy for the usual indications, it is advisable to use iodized oil, 40 per cent, in this way.

### FOURTH METHOD<sup>2</sup>

The fourth method is the intratracheal introduction of the oil by indirect illumination of the larynx. This method has been used in many patients, and has been found successful. The method used is to give the patient one-fourth grain of morphine combined with  $\frac{1}{150}$  grain of atrophine sulphate. The patient is then brought to the roentgenologic department and placed in the upright position. The tongue is pulled out as far as possible by the patient or an assistant. The larynx is then thoroughly anesthetized with a 20 per cent solution of cocaine combined with 1:1,000 solution of epinephrine hydrochloride. The cocaine solution and the epinephrine hydrochloride should be in the proportion 1:2. The application of the solution should be made every five minutes until the operator can touch the vocal cords without producing a cough.

A tracheal catheter connected with a syringe containing 3 per cent solution of procaine hydrochloride is introduced between the vocal cords. Five cubic centimeters of this solution is introduced into the trachea and bronchi. One must

spastic paralysis by surgical interruption of the sympathetic nerve innervation of the muscles involved, is based on the theory that a special function designated as "plastic tone" depends on the sympathetic nerve fibers, and that abolition of this plastic tonus will considerably relieve the pathologic spastic condition. Experimental research of many observers has failed to substantiate these observations.

*Anatomy of the Sympathetic Nervous System with Reference to Sympathectomy and Ramisection.*—Ranson,<sup>27</sup> after discussing the anatomy of the sympathetic nervous system, concludes that no satisfactory explanation has been presented for the hyperemia that follows periarterial sympathectomy, nor for the relief of the pain that some of these patients experience. It is well known that there are sensory fibers supplying the blood vessels, but these for the most part run centrally in the spinal nerves, and there is no reason to believe that they run in the periarterial sympathetic plexuses for any considerable distances.

*Danger in Use of Iodized Oil in the Diagnosis of Obstructive Lesions of the Spinal Canal.*—Owing to the fact that no unfavorable reports have been made of the use of iodized oil in the diagnosis of obstructive lesions of the spinal canal, Sharpe and Peterson<sup>28</sup> report three cases in which it was used with success as to diagnostic observations, but with aggravation of clinical symptoms and signs. So marked in one case was this aggravation that a laminectomy was performed and two encysted globules of iodized oil surrounded by numerous newly formed adhesions were removed. In all three cases the unabsorbed iodized oil was revealed by the roentgen ray in the spinal canal even after an interval of fifteen months following injection.

#### GROWTH DISTURBANCES

*Achondroplasia.*—Giaume<sup>29</sup> reports a case of achondroplasia, and in discussing the etiology of the condition says that while the clinical picture is well known, the etiology remains obscure, as is indicated by the various hypotheses that have been suggested. The theories that have been strenuously and authoritatively advanced, although numerous, may be grouped about three different conceptions, according to which the etiology may be sought in hereditary factors, in endocrine dysfunction and in toxic and infectious influences. He carefully discusses these theories, and then reports a personal observation, from a study of which he offers the following conclusion: On account of the hydramnios of the positive Wassermann reactions in the parents and in the patient, and the evident

27. Ranson, S. W.: J. A. M. A. 86:1886 (June 19) 1926.

28. Sharpe, William, and Peterson, C. A.: J. Bone & Joint Surg. 8:348 (April) 1926.

29. Giaume, C.: *Pediatrics* 34:359 (April 1) 1926.



part, the patient is placed lying on the right side; if the middle or upper lobe is diseased, it is best to lay the patient flat, and the head may be lowered slightly to map out the upper lobe better. The left lung is outlined by reversing these directions. It is possible to outline one lung at a time in this way. The roentgenograms must be taken as quickly as possible after the introduction of the oil.

If the patient will turn from one side to the other the oil will flow by its own weight into the contralateral lung. In roentgenograms that seem to show bilateral bronchiectasis, this may be interpreted merely as an overflow of the pus from the more diseased lung.

#### FIFTH METHOD<sup>4</sup>

The fifth is the simple method which consists in the injection into the pharynx of from 20 to 30 cc. of iodized oil, 40 per cent, in the following manner: The patient opens the mouth widely, the tongue is pulled far out of the mouth and the straight cannula, which is attached to an ordinary syringe filled with the oil, is placed horizontally at the region of the base of the tongue. The patient is then requested to take a deep inspiration, during which the oil is injected. Following the injection of the oil, eight or ten successive deep inspirations are then advised, the tongue being forcibly held out and the patient requested not to swallow.

In this clinic this method has been used in many cases with good results. If the patient has a more or less naturally anesthetic pharynx, the procedure is even easier. The plethoric type of person lends himself well to this. It may be tried in patients in whom mechanical irritation of the nasopharynx is contraindicated. It is not possible to inject as much oil with this method as with those in which complete anesthesia of the pharynx is used, but good roentgenograms are obtained in most cases.

The patient will cough up most of the oil within fifteen or twenty minutes, but the remaining opacities may be observed for months afterward. Excellent results have been obtained with this method, with little discomfort to the patient. Children do not lend themselves well to this procedure, and for them the first method is recommended.

#### COMMENT

The value of bronchography lies in the definite mapping out of lung structure, either normal or altered by pathologic conditions. It requires considerable experience to be able to interpret these shadows, especially with so dense or so opaque a substance. In view of the fact that the lung fields may extend in an anterior and a posterior direction from 6 to 12 inches (15 to 30 cm.), one can readily understand how superimposing shadows will complicate the roentgenogram, but the true interpretation will be made in conjunction with the physical signs and history. Many

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4. Lian, C.; Darbois, and Navarre, P.: Non-penetration dans la trachée des injections dites intra-trachéales faites par un procédé simplifié, *Bull. et mém. Soc. méd. d. hôp. de Paris* 46:470 (March 17) 1922.

*The Value of Irradiated Cholesterol in the Treatment of Rickets.*—Parsons<sup>33</sup> reports a severe case of rickets in which the child had been under treatment during the greater part of 1925. From the beginning of September, the child received cod liver oil, but with only slight improvement. During the last months of the year he was admitted into the hospital, and irradiated cholesterol was administered with the result that the rickets was cured.

*Neurologic Symptoms in Osteitis Deformans (Paget's Disease).*—Gregg<sup>34</sup> reviews a series of reported cases, making further analysis of the neurologic observations. He states that the disease is not rare, but that since roentgenologic examinations have been made there is a great increase in the number of cases. Early in the disease the patient complains of bone pains due to pressure caused by disturbances of the function of the nerves. Spontaneous fracture, joint pains, motor disturbances, neuralgia and paralysis occur. The diagnosis can generally be made by roentgenograms.

*Report of a Case of Solitary Fibrocystic Disease of the Humerus, Exhibiting Spontaneous Resolution; a Review of the Literature: Etiology and Treatment.*—Adams,<sup>35</sup> in reporting a case of solitary fibrocystic disease of the humerus exhibiting spontaneous resolutions, observes that the disease seems to form one of the many guises in which defective calcium metabolism disguises itself. He makes three divisions of his subject. 1. Three factors, therefore, enter into the etiology of fibrocystic disease: (a) vulnerable formative tissues of the metaphysis, especially at the upper end of the humerus and the extremities of the femur; (b) the site of maximum physical stress on bones, that is, near the shoulder, hip and knee, where strong muscles pull and twist, and (c) instability of calcium control, owing to defective parathyroid function. 2. The varying degrees to which the skeleton is affected by fibrocystic disease are easily explained. Thus, in the mildest cases there is a temporary disorder affecting one of the particularly susceptible regions, for example, the upper end of the humerus, and subsequent disappearance of the disease. In a moderate deficiency of parathyroid function, a solitary lesion occurs and persists, while in a severe disturbance, multiple foci manifest themselves. Finally, the diffusion of the disease throughout all the bones (von Recklinghausen's disease of bones) may be regarded as a malignant form. 3. In the monosseous type of fibrocystic disease of the bones, spontaneous cure has been known to occur in only about 4 per cent of cases. It remains to be seen whether this percentage can be augmented by the wider adoption of palliative treatment.

33. Parsons, L. G.: Brit. M. J. 1:519 (March 20) 1926.

34. Gregg, D.: Arch. Neurol. & Psychiat. 15:613 (May) 1926.

35. Adams, A. W.: Brit. J. Surg. 13:734 (April) 1926.

dense shadows in the roentgenogram may be tumor masses, collapsed lung tissue or cavities filled with secretion. The opacity of the iodized oil, 40 per cent, when introduced into the lungs of these patients will often give startling pictures of pathologic conditions that were not suspected.

The oil can be used in fistulous tracts to map out chronic empyema cavities and also bronchial fistulas, and when introduced in this way it rarely excites a cough. This substance has helped to show abscessed cavities that were connected with the empyema cavities through a bronchial fistula.

In pneumothorax cases, and especially in bronchiectatic cases, iodized oil, 40 per cent, shows well the collapsed bronchi.

Jacobaeus,<sup>5</sup> in a recent article, described how the iodized oil, 40 per cent, in pneumothorax cases has shown that bronchial tubes were seen in adhesions extending to the chest wall. One can easily see how it could be possible to sever lung tissue with the cautery in Jacobaeus' method and produce empyema and probably death.

To summarize the value of bronchography, it is of great benefit, in combination with careful physical examination, to those who have had considerable experience with suppurative lung conditions. It should not be used in any case in which simpler methods can be used. It shows excellently the bronchial tree with abnormalities present, and when properly used it is harmless.

The first method is recommended for children and the fourth and fifth methods for adults, and the second and third methods when bronchoscopy is performed for other purposes. The fifth method should be tried in adults before attempting the more complicated ones. If unsuccessful, then the fourth is the method of choice.

Recently, Iglauer<sup>6</sup> devised an intubation tube which prevents regurgitation of the oil. While this method has much to commend it, one should use means with as little instrumentation as possible to obtain the desired roentgenogram.

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5. Jacobaeus, H. C.; On the Cauterization of Apex Adhesions and the Importance of Bronchography in Pneumothorax Treatment of Tuberculosis, *Acta Tuberc. Scandinav.* 1:1 (Jan.) 1925.

6. Iglauer, Samuel: Use of Injected Iodized Oil in Roentgen-Ray Diagnosis of Laryngeal, Tracheal and Bronchopulmonary Conditions, *J. A. M. A.* 86:1879 (June 19) 1926.

# TRANSACTIONS OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

NINTH ANNUAL MEETING, MONTREAL.  
SEPT. 30, OCT. 1 AND 2, 1926

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is never used in children. A swab of 20 per cent cocaine solution is carried through the larynx, using the direct laryngoscope prior to the introduction of the bronchoscope in adults. After the introduction of the bronchoscope the secretions are thoroughly aspirated and a 20 per cent cocaine solution is applied by means of swabs to the trachea and bronchi, particularly to the portion of lung that it is desired to examine. The excess of cocaine solution is aspirated.

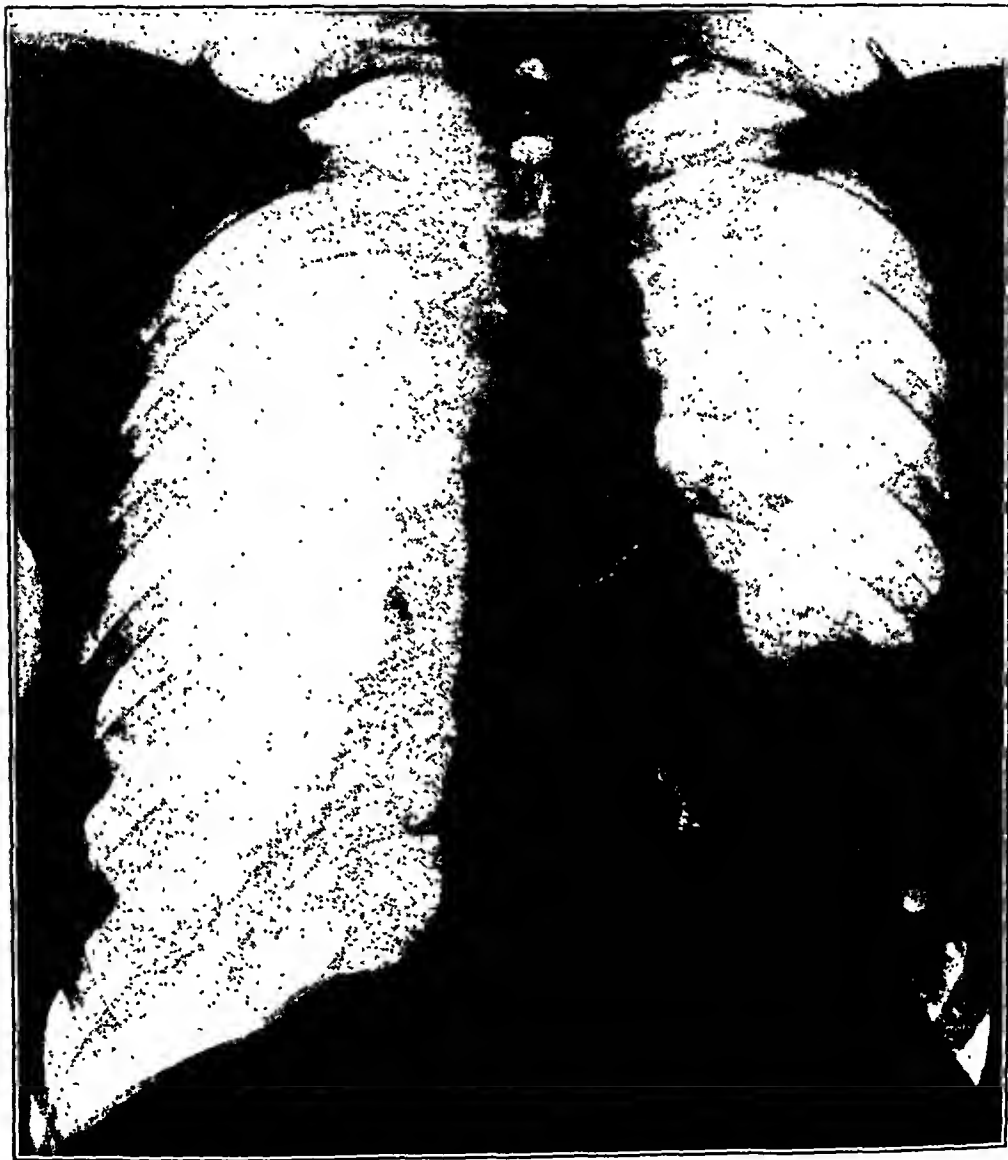


Fig. 1.—A patient, aged 24, with abscess of the left lung; there is an opaque area of uniform density in the left lower lobe.

In children aspiration through the bronchoscope is carried out without the application of local anesthesia. If bismuth subcarbonate is to be used, it is insufflated into the area desired, and the patient is sent to the roentgenologist and should not cough until after the roentgen-ray examination. If iodized oil, 40 per cent, is used after the insertion of the bronchoscope and aspiration of secretions and anesthetizing with cocaine, the portion of the lung that it is desired to examine is placed at the lowest level by raising or lowering the head

# BRONCHOGRAPHY

## INJECTION OF IODIZED OIL, 40 PER CENT \*

J. J. SINGER, M.D.

ST. LOUIS

In the study of the roentgenograms of the chest of patients who have had a bismuth or barium meal for gastro-intestinal study, one occasionally encounters a startling picture of the bronchi outlined by barium. This accident is due to a fistulous tract caused by ulceration of the esophagus into the trachea. It has been noticed in these patients that fits of coughing occur during the swallowing of the barium. We have learned to look for ulceration of the esophagus in patients who suddenly begin to cough during a gastro-intestinal examination.

Jackson<sup>1</sup> of Philadelphia introduced bismuth subcarbonate in finely powdered form through a bronchoscope into the lobe of the lung that he wished to study. He obtained excellent roentgenograms by this method. Owing to the fact that bronchography through a bronchoscope requires the greatest skill, it was natural that such a practice did not become popular. Since the introduction of iodized oil, 40 per cent, as suggested by Sicard and Forestier,<sup>2</sup> we have been able to perform lung mapping without any danger to the patient and with considerable value in diagnosis.

There are five methods of introducing iodized oil, 40 per cent:

1. Through a trocar needle, resembling a tracheotomy tube, into the trachea, under sterile precautions.<sup>3</sup>
2. Under direct laryngoscopic examination with the patient lying on the back, with the head extended over the table.
3. Through the bronchoscope introduced directly into the lung.
4. Through a tracheal catheter introduced under indirect illumination of the larynx.
5. By the injection into the pharynx of 20 cc. of oil, while the patient pulls out his tongue as far as possible. The patient should be trained to take many successive deep breaths following the injection of the oil.

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\* From the Department of Medicine and Surgery, Washington University School of Medicine, and Barnes Hospital.

1. Jackson, Chevalier: *Bronchoscopy and Esophagoscopy*, Philadelphia, W. B. Saunders Company, 1922.

2. Sicard, J. A., and Forestier, J.: *General Method of Radiological Exploration with Iodized Oil*, Bull. et mèm. Soc. mèd. d. hôp. de Paris 46:463 (March 10) 1922.

3. Armand-Delille, P., and Gelston, C. F.: *The Diagnosis of Dilatation of the Bronchi in Children by Means of the Injection of Iodinized Oil*, Am. J. Dis. Child. 28:530 (Nov.) 1924.

## REPORT OF CASES

CASE 1.—The posterior division of the left lower lobe bronchus was completely blocked by a plug of inspissated secretion. It was necessary to remove the plug with the forceps before the bronchus tributary to the diseased area of lung could be entered. The patient, a man, aged 24, who gave no previous history of pulmonary disease, developed pneumonia. He was ill for a period of

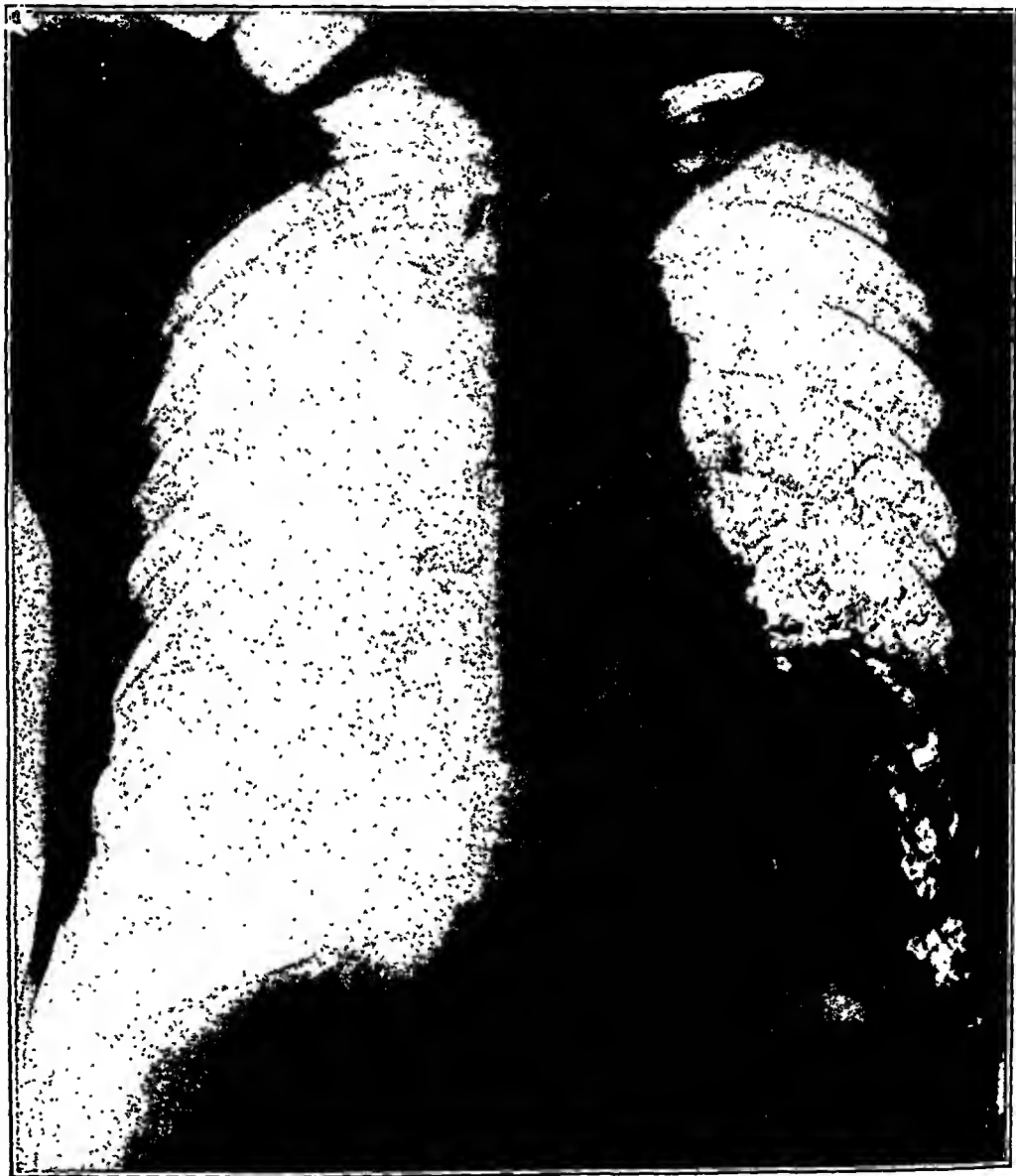


Fig. 3.—Same patient as shown in figure 1 after bronchoscopic aspiration of the pus and introduction of iodized oil into the posterior division of the bronchus of the left lower lobe; the cavity with the abscess is outlined by the opaque substance. The patient made a complete recovery following seven bronchoscopic treatments at weekly intervals (roentgenograms by Drs. H. K. Pancoast and E. P. Pendergrass.)

ten days, with signs and symptoms typical of lobar pneumonia. The temperature became normal by crisis; the productive cough subsided at the end of another week, and the man was discharged from the hospital. The patient's

The initial coughing rapidly abates with the anesthesia of the tracheal mucous membrane. The operator then attaches the syringe containing the iodized oil, 40 per cent, and begins the injection, which should not be too rapid. During the course of the injection or immediately afterward, it is wise to elevate first one side of the patient and then the other in order to facilitate the distribution of the oil. If it is suspected that one side only is affected, the lower position for that side may be maintained entirely. From 8 to 10 cc. of oil suffices, as a rule, to inject the bronchial tree of one lung in children aged from 7 to 14 years, and requires from six to eight minutes or less.



Fig. 1.—Normal distribution in patient sitting upright of iodized oil, 40 per cent, injected into both lungs at the same time.

#### SECOND METHOD<sup>1</sup>

The second method can be used only by laryngologists especially trained for this work. The advantage of this method is that the operator can directly visualize the vocal cords and introduce a tube into the trachea, through which the iodized oil, 40 per cent, can be injected.

Before the injection is begun, the patient is told that he will feel a disagreeable pressure on the neck, and will probably think that he is being choked. It is necessary to explain to him that the procedure is harmless and absolutely free



cated with the bronchus. Roentgen-ray examination the following day showed a fluid level in the area that had previously shown a uniform density, indicating a partial reaccumulation of pus following aspiration (fig. 2).

Iodized oil, 40 per cent, was then introduced bronchoscopically, after the lung had been aspirated free of pus, and a cavity of considerable size was outlined in the posterior portion of the left lower lobe (fig. 3). Bronchoscopic treatment was continued, and the patient is now well. The lung is entirely clear.



Fig. 5.—Abscess in the posterior portion of the lower lobe of the left lung after the bronchoscopic introduction of iodized oil (roentgenogram, by Dr. E. J. Bertin).

In this case, without the removal of the plug in the bronchus it would have been impossible to introduce iodized oil, 40 per cent, into the cavity.

CASE 2.—A woman, aged 51, had had a tuberculous infection of the left lung two years before admission. Under the care of Dr. Lawrence Flick of Philadelphia, she had gained 35 pounds (15.9 Kg.) in weight and had been in good health until eight months before her admission, when she developed influenza with pulmonary symptoms. She had not completely recovered from this illness. Cough with profuse purulent expectoration had persisted, with irregular fever at times and toxic symptoms. Roentgen-ray examination showed

wait five minutes or more until the cough reflex is entirely abolished. If this does not result, it is useless to attempt the introduction of the oil as the oil will immediately be coughed out and will probably be swallowed.

The oil should be slightly warmed before it is used, as the operator will find it difficult to force the substance through the tracheal catheter.



Fig. 2.—Patient O. G., March 25, 1926, after thoracoplasty for tuberculosis; the bronchial tree is not visible.

When the patient is ready for the introduction of the tracheal catheter, he may be in a sitting position. Under the indirect illumination of the pharynx and larynx, the tracheal catheter or even an ordinary urethral catheter is introduced between the cords into the trachea. The warm oil is now injected through the catheter into the lung, and the patient immediately placed in the position that the examiner wishes to outline. That is, if the right lower lobe is the diseased

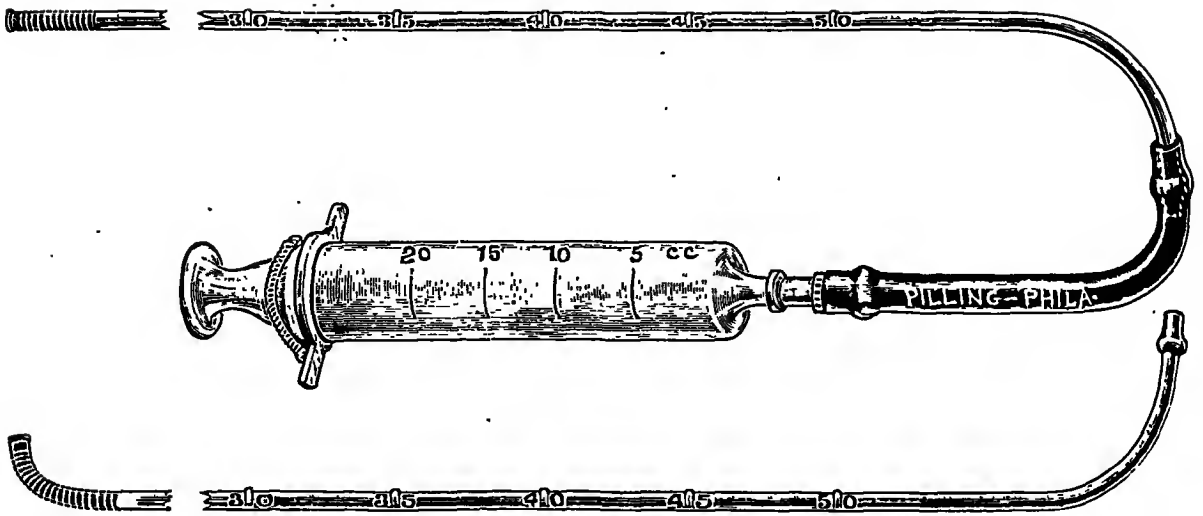


Fig. 7.—Tube set for instillation of iodized oil. The set consists of a straight flexible tipped (Lynah) tube and a curved flexible tipped (Lynah) tube to get around the corner; tubes are graduated at 5 cm. intervals to measure the depth of insertion. A rubber tube is interposed between a Luer syringe connection and the tube so that flexibility is obtained between the tube held by the bronchoscopist and the 20 cc. syringe that contains the oil for instillation.

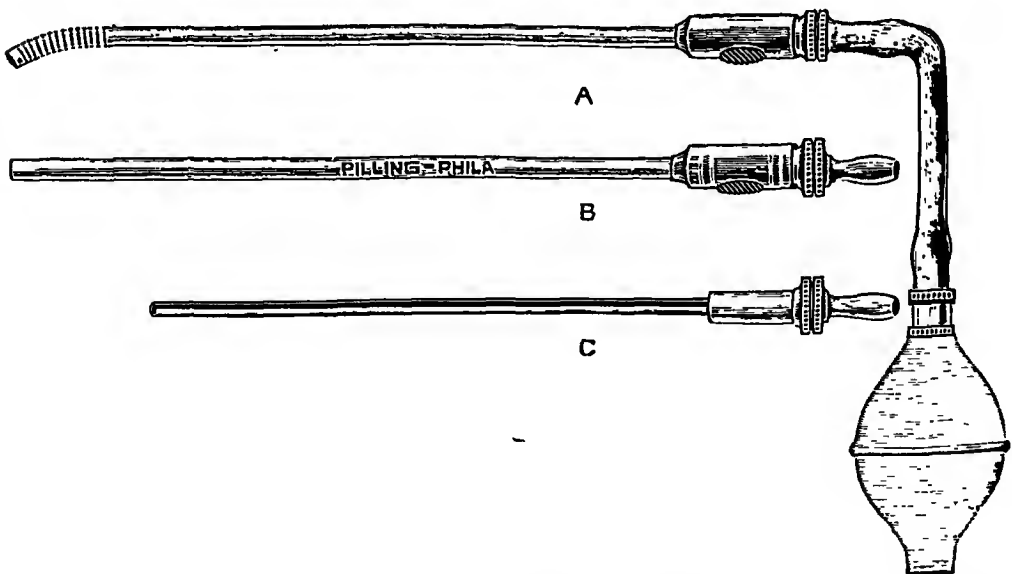


Fig. 8.—The bronchoscopic bismuth insufflator, devised by Dr. L. H. Clerf, consists of a flexible tipped tube (A), straight tube (B), gutter carrier for powder (C) and a hand bulb for insufflation.



Fig. 3.—Patient O. G., May 20, 1926, after the injection of iodized oil, 40 per cent, into the left lung; the bronchi are collapsed and no finer lung markings are visible.

# PNEUMONOGRAPHY WITH IODIZED OIL, 40 PER CENT, BY THE BRONCHOSCOPIC METHOD

THE BRONCHIAL TREE, WITH OBSERVATIONS MADE FROM  
ONE HUNDRED INJECTIONS \*

DAVID H. BALLON, M.D.

AND

HARRY C. BALLON, M.D.

MONTREAL

Accurate anatomic studies of the bronchial tree, the result of investigations by the various methods of injection in postmortem specimens, were made many years ago. These methods had many disadvantages. In order to be successful, they usually had to be carried out with a fusible metal. The resulting casts of the bronchial tree were necessarily incomplete. It was impossible to control the rate of injection-flow of this not easily diffusible metal. The postmortem changes in the tissue, the obstruction from accumulated respiratory secretion, as well as the inability to maintain a uniform pressure, were some of the factors that produced what must be considered as an imperfect representation of the bronchial tree. For, although the relationship to the heart and great vessels was in many instances demonstrated, an outline of the pulmonary parenchyma and bony thorax was found to be lacking. Naturally, such studies in the living subject made with a readily injectible and easily diffusible substance offer much greater opportunities for studying and understanding both normal relationships and pathologic conditions.

In this connection, however, it is well to appreciate that even in injections made in the living, there are many factors which may influence or alter the resulting picture. These will be mentioned in the course of the article, as these factors must be taken into account in interpreting the roentgenograms of the injections.

The advantages that iodized oil, 40 per cent, has over the other agents that have of late been employed to outline the bronchial tree have been considered elsewhere.<sup>1</sup> Suffice it to say, that in contrasting past and present methods, one but emphasizes the fact that various methods seek to achieve the same results by different procedures.

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\* From the bronchoscopic and surgical departments of the Royal Victoria Hospital.

1. Ballon, D. H.: The Injection of Lipiodol as an Aid in the X-Ray Diagnosis of Bronchopulmonary Lesions Including Tuberculosis, Preliminary Report, *Canad. M. A. J.* 15:995-999 (Oct.) 1925.

# TECHNIC OF BRONCHOSCOPIC INTRODUCTION OF BISMUTH SUBCARBONATE AND IODIZED OIL, 40 PER CENT, FOR PNEUMONOGRAPHY

GABRIEL TUCKER, M.D.

PHILADELPHIA

The introduction of the radiopaque substances, bismuth subcarbonate and iodized oil, 40 per cent, into the lung for pneumonography has been found to be harmless when limited quantities are used. The substances themselves are readily coughed out, and during their sojourn in the lung have a medicinal value (fig. 6).

The bronchoscopic method of introduction gives a direct examination of the trachea and of the main bronchi of each lobe of the lung. In addition to the diagnostic value, the bronchoscopic method permits of the removal of obstructing secretions and granulations, and when an organic stenosis of the bronchus exists, it allows of the introduction of the substance by sight through the stenosis into the portion of lung distal to the narrowed bronchus. By this method the substance can be accurately placed in any desired portion of the lung and a positive pneumonogram obtained with the minimum quantity of opaque substance.

Bismuth subcarbonate, when insufflated bronchoscopically after thorough aspiration of secretions, will outline satisfactorily the tracheal and bronchial walls and bronchiectatic cavities of the larger bronchi. Iodized oil, 40 per cent, is most satisfactory in the periphery of the lung and where the abscess cavity communicates with the smaller bronchi. The cavity should be aspirated as free of pus as possible because, although iodized oil, 40 per cent, will displace air in the cavity, it will not so easily displace pus that fills the cavity completely. After aspiration iodized oil, 40 per cent, should be introduced through a flexible tipped tube into the larger tributary bronchi and be allowed to flow into the abscess cavity by gravity, the patient being placed in the proper position to accomplish this.

## TECHNIC

The technic is that of bronchoscopy, with the addition of the introduction of the opaque substances through the bronchoscope. The bronchoscopic technic is as follows: The patient is prepared by withholding all food for six hours. One hour before operation, morphine sulphate, one-fourth grain, and atropine sulphate,  $\frac{1}{150}$  grain, are given to adults. The patient is brought to the operating room on a litter. Two applications of 10 per cent cocaine solution are made at five minute intervals to each pyriform sinus. The patient is then placed on the table in the dorsal recumbent position and the bronchoscope introduced according to the Jackson technic. In children under 12 years of age a proportionate dose of morphine and atropine is given, but no local anesthetic is used. Cocaine

of infants contain the same elements as those of the adult, their size only being different. The subsequent growth would appear to be dependent on an increase in the size of the alveoli without any addition to their number.

The roentgenographic appearance of the normal bronchial tree after the injection of iodized oil, 40 per cent, at various age periods likewise appears to be constant.

The larger tubes possess only as much cartilage as will ensure their patency, and are not in the ordinary sense rigid tubes. The smaller bronchial tubes are totally deficient in cartilage and receive instead of

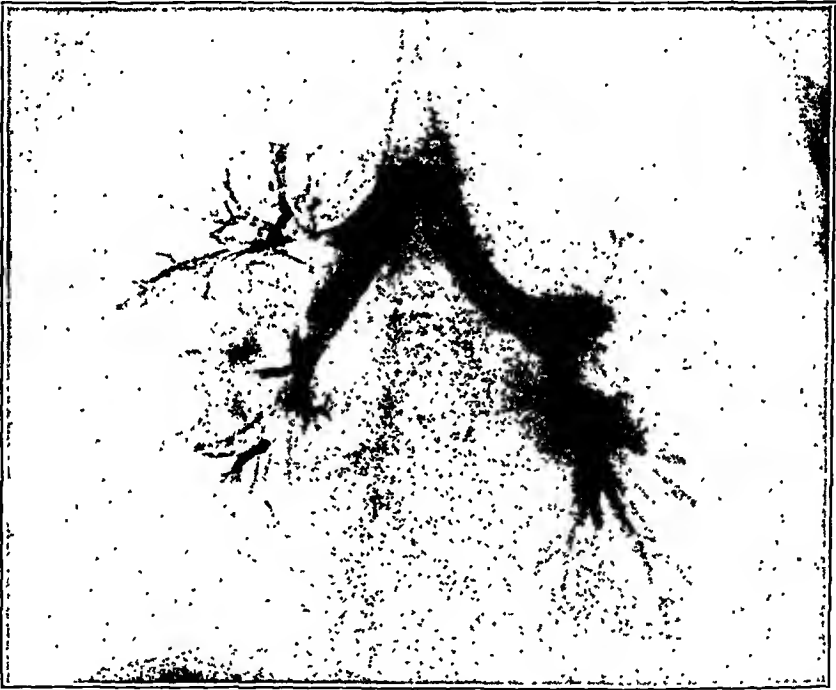


Fig. 1 (case 1).—Centrally placed trachea with long main stem bronchus and rather wide tributaries in a person with a long thick chest; 20 cc. of iodized oil had been injected. The underlying condition is an abscess of the lung in the right lower lobe; the abscess cavity is of the narrow neck type so that it has failed to fill; the iodized oil has reached the alveoli at the base of the left lung (roentgenograms by Dr. A. H. Pirie).

give support. They are thus frequently the site of disease. Of their elastic and connective tissue no mention need here be made.

The trachea lies normally slightly nearer the right upper lobe than the left and nearest the right upper lobe at its bifurcation (fig. 1). Bifurcation usually has been stated as taking place at the level of the superior border of the fifth thoracic vertebra. Injections have shown that this may vary frequently, even in the normal subject. The left bronchus is more oblique and smaller than the right, which is short and wide, and passes down as a direct continuation of the trachea. The

of the table and by turning the patient on the side to be examined. The oil is then injected through a flexible tipped instillation tube. The tube is withdrawn, and the patient's position is maintained after the withdrawal of the bronchoscope while the patient is sent to the roentgen-ray room on a litter. The injection may be made on the fluoroscopic table after the instillation tube is introduced by sight. This assures correct localization. The roentgenograms can be made, of course, on the same table, if the apparatus will permit it. In the introduction of iodized oil, 40 per cent, it is important that it be placed in the larger bronchi and allowed to go into the periphery of the lung by gravity.



Fig. 2.—Same patient as shown in figure 1. A plug of inspissated secretion was removed from the posterior division of the bronchus of the left lower lobe bronchoscopically. The roentgenogram, made the day following the bronchoscopic aspiration, shows a fluid level in the area that was uniformly dense before aspiration, indicating that there had been some reaccumulation of fluid in the abscess.

In a number of patients I have found blocking of the bronchi by granulations, organic stenosis or inspissated secretions so extensive that the opaque substance could not be introduced without mechanical removal of the obstruction by means of forceps or dilatation. I report two illustrative cases.



connection, it is well to remember that the position of the patient during the performance of an injection should be considered before injection as well as after injection; for when injection is carried out with the patient lying on his back, the posterior half only may inject; so, too, with the patient in the sitting position, the anterior half may be more readily filled. Lateral views will help to show this.

*Relation of the Circulation to the Bronchial Tree.*—The branches of the pulmonary artery follow closely the course of the bronchial tree, dividing more frequently, however, in their remote ramifications (fig. 2). Pulmonary veins accompany the bronchi and arterial branches for but short distances. They deviate in direction from them frequently. They are never parallel to the bronchial tree, which they cross repeatedly. The arterial system may be said to be a fairly close reduplication of the bronchial tree. The artery and the bronchus enter the lung from above, the vein approaches it from below. Therefore, if we but consider the many branchings of the bronchial tree, the manner in which the circulation both follows it and crosses it, we cannot but feel that ordinary roentgen ray has a difficult task to demonstrate anything but broad markings of the normal bronchial tree. The nonbranched portion and those branches which extend posteriorly from the hilum to the base are the more common branches to show up.

Of the lymphatics, we may state that on observing the disappearance of iodized oil from the lung, some of it appears to go to the glands at the hilum of the lung, where it may persist for a considerable period of time, presenting the appearance of a calcified gland.

*Abnormalities of the Bronchial Tree.*—Injections have shown that variation of the level at which division of the trachea takes place normally is not rare. Variation is frequent in disease, particularly in those conditions in which there is marked fibrosis or pressure effects, as in chronic fibroid phthisis, disease of the mediastinum or pleura, or in cases of bronchiectasis in which peribronchial induration has produced much distortion of the bronchial tree and altered the position of the movable points of the main bronchi. One might expect, and injections verify the belief, that in cases in which the diaphragm is raised and adherent, the pleura thickened and the heart displaced, the bronchial tree will often be redundant, particularly in its main stems. So, too, in chronic fibroid disease it does not seem unlikely that during the process of fibrosis there should result a distortion of the bronchial tree. For contracted ribs and scarred apex, as well as the altered position of an adherent and partially immobilized diaphragm, must with the progress of time appreciably alter the contour and position of a dilatation or cavity, particularly of the bronchiectatic type. Is this nature's attempt at rest? Is one also to feel that in a person whose lung shows much fibrosis, and who has been ill for a long time, the benefits to be obtained

condition did not improve as rapidly as is usual in such cases. He failed to gain strength and weight, and had a slight, unproductive cough. Examination of the chest showed evidence of a pathologic process in the left lower lobe posteriorly. The pleura was clear. There was no fever and no expectoration. Roentgen-ray examination showed a shadow of uniform density in the left lower lobe (fig. 1). The man was referred to Dr. Stengel's service at the University of Pennsylvania Hospital. The question arose as to whether the lesion in the lung was an unresolved pneumonia lesion or a tumor. Diagnostic bronchoscopy was requested, and on examination of the left lung no abnormal secretion was found in the left main bronchus, but the orifice of the posterior division of the



Fig. 4—A woman, aged 50, with compression stenosis of the left main bronchus and bronchiectasis, after the insufflation of bismuth subcarbonate bronchoscopically; there is stenosis of the left main bronchus, with dilatation of the larger bronchi in the upper and lower lobes of the left lung (roentgenogram by Dr. H. K. Pancoast).

bronchus of the left lower lobe was found completely blocked by a whitish substance that could not be removed by aspiration. It had the appearance of a foreign body. The bronchial mucosa surrounding it was inflammatory and thickened. The plug of organized secretion was removed with forceps and was found to extend about a centimeter into the bronchus. After its removal, a considerable quantity of blood stained pus was discharged into the stem bronchus, and an additional amount was aspirated from the abscess that communi-

advantage in empyema with bronchial fistula in determining the amount of expansion of the lungs and the degree of obliteration of the empyema cavity.

At the present time, both methods are being employed, roentgenograms being taken in the anteroposterior position, lying and sitting, and in the lateral prone and standing positions. During inspiration, a general expansion of bronchi and bronchioles begins near the hilum and spreads in all directions. The greatest expansion is downward, at and near the hilum, less outward about the midlung, and least upward at the apex. Near the diaphragm the respiratory movements in the

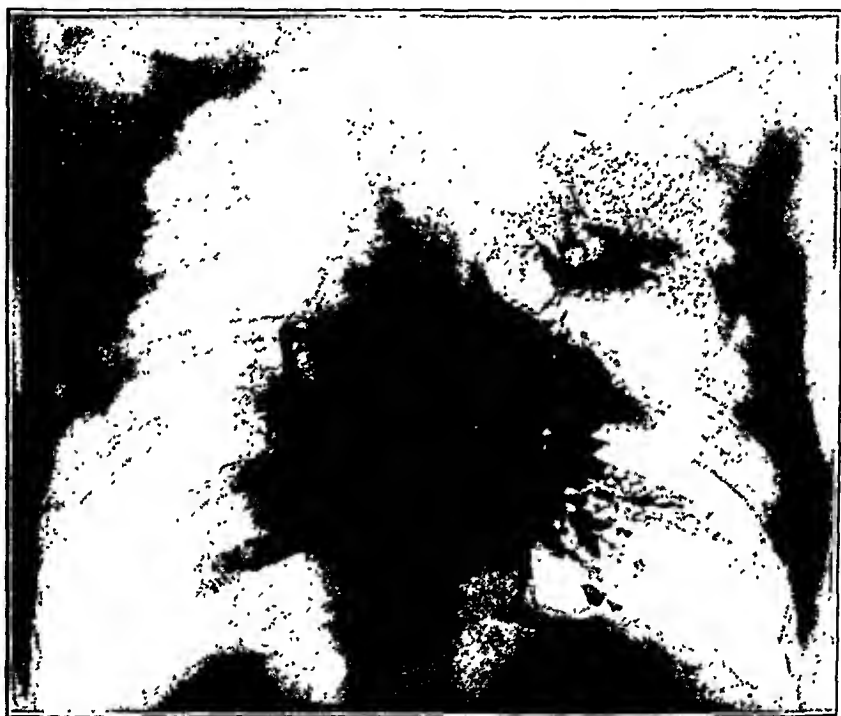


Fig. 3 (case 3).—Respiratory movements in bronchiectasis after the injection of 20 cc. of iodized oil: a double exposure taken on one film during deep inspiration and full expiration, with the patient in the dorsal decubitus position. The shadow cast during inspiration is larger than that during expiration. The rib movements and the excursion of the diaphragm should be noted.

bronchioles are upward and downward, with excursions of about half an inch (1.2 cm.). As the middle of the lung is approached, the movement is more or less horizontal. Observations on the lung parenchyma are less definite than in the bronchioles, owing to the diffuse shadow cast by the parenchyma. The darker shadows observed in some areas of the lung are due to superimposed iodized oil. During inspiration the iodized oil separates; during expiration it is jammed together and is therefore cloudy (fig. 3).

Rib movement normally is equal and is about one-fourth to three-fourths inch. The movement of the clavicle is more than 1 inch

a peribronchial thickening in the region of the left hilum, and a diagnosis of bronchiectasis was made. A diagnostic bronchoscopy was requested by Drs. Isabel, Ralph, Max Gorpp and Margaret Butler, to whom the patient had been referred. On bronchoscopic study, I found stenosis of the left main bronchus due to a bulging outward of its internal wall. The mucosa was inflammatory, and the lumen of the bronchus appeared as a crescent-like slit on the external bronchial wall. Large amounts of pus were aspirated from the area of lung



Fig. 6.—The same patient as shown in figure 5 four months later; the opaque substance is no longer present in the lung and the evidence of abscess has disappeared. Three bronchoscopic treatments at weekly intervals had been given. The patient was symptomatically well.

distal to the stenosis. After aspiration of pus through the stenosed bronchus, the insufflation tube was introduced and the area of lung distal to the narrowed bronchus was insufflated. Bismuth subcarbonate was insufflated also in the bronchus above the stenosis and in the trachea at the bifurcation. The pneumonogram demonstrates the stenosed bronchus, as well as the dilatation of the bronchi distal to the point of stenosis (fig. 6).

Here again the blind introduction of the opaque substance would have failed to give a satisfactory pneumonogram, because it was necessary to dilate the stenosis before the bismuth subcarbonate could be

grams taken in varying lateral positions are often definitely different, and at times demonstrate how one can draw conclusions as to the effects of posture.

One should then sum up all information obtained, and attempt to explain signs and symptoms on the basis of observations that have been made, for only in this way can prognosis be made. Before undertaking treatment, particularly in conditions of the bronchial tree which are so often chronic and extensive, it should be made certain whether the complaints are amenable to treatment.

#### DISEASES OF THE BRONCHIAL TREE

Diseases of the bronchial tree may be classified as those that act as a hindrance to respiration or those that affect the lumen by forces either from within or without. They are often but expressions of abnormalities. The trachea is often the seat of inflammations which are usually secondary. Displacements and deviations of the trachea are likewise due to extratracheal mechanical factors. The rôle of the foreign body, which has been so admirably described by Jackson,<sup>7</sup> or tracheo-esophageal fistula, needs only to be mentioned. An enlarged thyroid gland, particularly of the substernal type, as well as intrathoracic swellings, may alter the shape of the trachea considerably, acting purely as mechanical factors. The main bronchi in their extrapulmonary and nonbranched intrapulmonary portions by virtue of their position are naturally frequently subjected to stress and strain. They may be the site of stenosis and new growth. Enlarged glands about the hilum may give expression to their existence by pressure, and as such are being recognized as an etiologic factor in the production of certain types of bronchial asthma. The branched intrapulmonary bronchi are the most frequent sites of disease, such as bronchiectasis, putrid bronchitis, bronchiolitis and bronchiolectasis.

With regard to bronchiectasis, the true congenital or atelectatic type is rarely encountered. Bronchiectasis in which the dilatations are marked and the cough and expectoration relatively slight, is so frequently encountered in children, however, that one feels that dry bronchiectatic dilatations often may be present from birth, at least for many years before they attract attention. Several cases of what the French call "*forme sèche hémoptoïtique de la dilatation des bronches*" have been reported by Bezançon<sup>8</sup> and others. Table 1 illustrates our classification of bronchiectasis, made possible by iodized oil.

7. Jackson, Chevalier: Chronic Nonspecific Infections of the Lungs, J. A. M. A. 87:729-736 (Sept.) 1926.

8. Bezançon; Weil; Azoulay, and Bernard: *Forme Sèche Hémoptoïtique de la Dilatation des Bronches*, Presse méd. 32:157-159 (Feb. 20) 1924.



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7. Jackson, Chevalier:  
M. A. 87:729-736 (Sept.) 19
8. Bezançon; Weil; Azu  
la Dilatation des Bronches,

This report is an accumulation of facts, the results of observations following injections and dissections. Only those observations which may serve as a clinical aid are recorded.

#### METHODS

In our investigations the bronchial tree in the living was injected with iodized oil, 40 per cent, by the bronchoscopic method.

Dissections in fresh specimens were carried out under water. Sodium iodide, 12 per cent, as well as iodized oil, 40 per cent, was used to inject the bronchial tree in postmortem specimens, but both were found to give poor results. The blood was injected with barium sulphate in gelatin after Gross' <sup>2</sup> method, and stereoscopic roentgenograms were taken. The bronchial tree was then injected with paraffin and its relationship to the circulation studied.

#### FUNCTIONS AND CHARACTERISTICS OF THE BRONCHIAL TREE

*Functions.*—The bronchial tree, in addition to its main functions, acts as a supporting substance to the alveolar structure. Its various fixed and movable points are important factors in the performance of the various respiratory movements. In addition to respiratory movement, the bronchial system has also as its function not only the admittance of gases, but also the discharge of fluids and mucus. Therefore, one must also consider the normal contractility of the bronchus as a factor in expelling secretions and in the performance of respiration. This has been admirably looked after in that the system consists of central tubes of large diameter which receive short tributaries. The central tube is larger in a long, thin chest, while in a thick chest it is shorter and wider, the tributaries being longer.

*General Considerations.*—A clinical knowledge of the many bronchial branchings does not appear necessary, although some appreciation of the more common divisions and the principles which govern these divisions is required. The position and arrangement of the larger tubes are fairly constant in man. The main bronchi are unequal, yet it would appear that they are the products of a bifurcation. Their inequality is probably due to the position of the heart. It is almost an invariable rule that of two diverging bronchi, the smaller one diverges most from the position of the parent tube; this also holds good for the tracheal bifurcation, the left product of which is more oblique as well as smaller than the right. It has been proved by calculation by Ewart <sup>3</sup> that the lungs

2. Gross, Louis: The Blood Supply to the Heart, New York, Paul B. Hoeber, 1921.

3. Ewart, William: The Bronchi and Pulmonary Blood Vessels, London, Baillière, 1889.





Fig. 8 (case 8).—Bronchiectasis of the bronchiolar type, showing bead formation, after the injection of 20 cc. of iodized oil into the right lung (patient of Dr. W. F. Hamilton).



Fig. 9 (case 9).—Tuberculous bronchiectasis of the diffuse type, resembling the fingers of a glove, after the injection of 30 cc. of iodized oil into the bronchi. This type, which extends well to the periphery, responds well to methods of compression (patient from Dr. Edward Archibald's service).



Since iodized oil has been introduced into roentgenology, it has been noted that the treatment of the associated bronchiectasis plays no small part in the problem of the surgery of pulmonary tuberculosis.

In our classification of bronchiectasis, we feel that the fact as to whether the bronchiectasis extends well to the periphery or is purely confined to the medial and lower half of the lower lobe should be of importance in estimating the amount of compression that thoracoplasty will produce (fig. 11). In the former case, when dilatations extend to

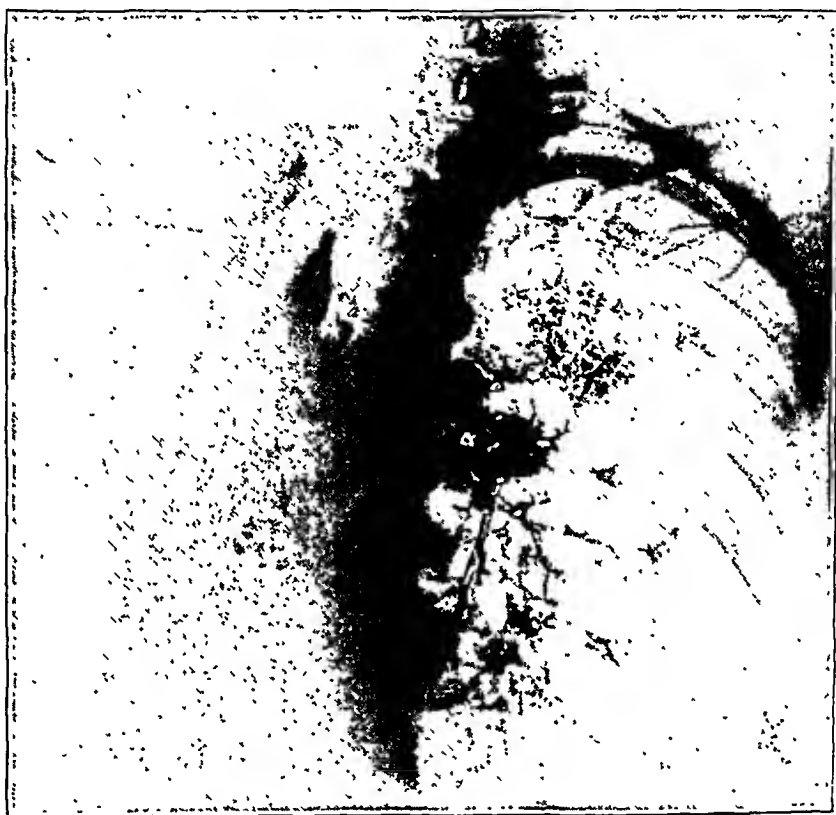


Fig. 11 (case 10).—Tuberculous bronchiectasis following a third stage of thoracoplasty, after the injection of 25 cc. of iodized oil, Feb. 18, 1926. This roentgenogram illustrates how further compression may fail to affect this type of bronchiectasis (patient of Dr. Edward Archibald).

the periphery, methods of collapse should undoubtedly in many cases remove these factors, which have produced and caused these dilatations to persist. In the latter instance, when the dilatations are basal, the result after further collapse may not be so complete.

Iodized oil sinks only to a certain level in a bronchiectatic tube, and persists longer if respiratory movement is insufficient. Is phrenicotomy beneficial in such a case, that is, in cases in which thoracoplasty also has been performed and the type of bronchiectasis already described has persisted?

from further methods of collapse must often of necessity be of questionable value? Only observations made before and after injection will reveal what surgical methods have to offer in these many and varied types of lesions before the undertaking of treatment.

It becomes obvious that stenosis or compressions of bronchi prevent the filling up of the corresponding area when injected. The more common stenoses which affect the nonbranched intrapulmonary portion of the bronchial tree are usually inflammatory in origin although they are not infrequently due to neoplasm.<sup>4</sup> Behind these stenoses there may be an associated lesion, such as bronchiectasis or abscess. It has recently been pointed out by one of us,<sup>5</sup> in a review of ninety-four cases of abscess of the lung, that where there are open bronchi communicating with an external wound, a previously stenosed bronchus may become a dilated one, while in the process of repair further bronchial dilatations may develop and persist.

The branched pulmonary portion of the bronchial tree may likewise be affected by acute diseases of the pleura and lungs. Typical pneumonia, which terminates in chronic induration, may lead to thickenings and adhesions about these bronchi.

The terminal bronchioles are so intimately associated with the alveoli that lesions of the latter are certain to affect the former. Bronchial tubes do not anastomose; true dilatations, therefore, cannot be due to fusions. The T shaped branchings may, however, lead to culdesac formation, particularly in the lower lobe, which is the common site of bronchiectasis in children. These sacculations have been seen to reach the size of a hen's egg.

#### STUDIES OF RESPIRATORY MOVEMENTS

In the first studies of respiratory movements by one of us,<sup>6</sup> inspiration and expiration were registered on separate roentgenograms. Later, a double exposure was made on the same film, during deep inspiration and full expiration. A double shadow is thus cast, in which the shadow cast during inspiration is larger than that during expiration. In this way, one can compare the changes occurring in the bronchi and bronchioles during respiration. This method may also be employed with

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4. Ballon, D. H.: Primary Carcinoma of the Bronchus with Abscess of the Lung, to be published.

5. Ballon, H. C.: The Value of Lipiodol in the Diagnosis and Treatment of Abscess of the Lung, to be published.

6. Ballon, D. H.: Lipiodol in the Diagnosis of Bronchopulmonary Lesions by the Bronchoscopic Method: Report of Fifty Cases, *Arch. Otolaryng.* 3:403-422 (May) 1926.

FACTORS THAT AFFECT THE FLOW AND DISTRIBUTION  
OF IODIZED OIL

Many factors normally affect the flow and distribution of iodized oil through the bronchial tree; the method of injection and the position of the patient have been referred to. In disease, the amount and the nature of the secretion in the tubes has likewise been noted. The bronchoscopic roentgenogram showing the caliber of the tubes during respiration and in various positions reveals well the benefits of postural treatment. Although the cough reflex helps to expel secretions from bronchiectatic tubes, the patient with bronchiectasis will often state that the only times he is able to bring up the really heavy sputum is when the carina is irritated or he becomes overheated. This sputum is usually present in the dilatations beyond the level of injection, and otherwise can often be brought up only by bronchoscopic aspiration. When iodized oil is employed by the bronchoscopic route, it should yield information that will help to increase the good results of postural drainage; it should reveal the shortcomings of present methods.

## ROENTGEN-RAY REPORT ON THE BRONCHIAL TREE

The usual roentgen-ray reports on the bronchial tree are unsatisfactory and often confusing. Such reports as "calcification at the root of the tree and intensification of the bronchial tree through both lungs" are often disconcerting. A report of this nature in the presence of chronic cough and expectoration not only fails to give any information as to the site and extent of the disease, but suggests that the condition is bilateral. In the absence of a positive shadow, the patient is placed on symptomatic treatment, and is told to report to an outdoor clinic for observation; years often go by before a positive diagnosis is made. Many of these conditions are bronchiectatic, and although it is perhaps expecting too much to hope for many cures in chronic bronchiectasis, still one should be able to produce more improvement and prevent certain conditions from progressing.

The limitations of the ordinary roentgen-ray report of the bronchial tree, however, must be expected. For as we have already noted, it is normal frequently for the bronchial tree to divide, and it is so repeatedly crossed by part of the pulmonary circulation that one can hardly expect anything but a mere outline of the main stems. In diseases affecting the bronchial tree, the branches must frequently be bent. Peribronchial inflammation and adhesions must likewise affect the picture.

## VALUE OF POSTURAL DRAINAGE

The value of postural nonsurgical drainage is entirely dependent on the type of lesion, its site and the nature of the underlying pathologic lesion. A narrow, partially rigid tube affected by stenosis will not

(2.5 cm.), and seems to be greater in the direction of the apexes than toward the base. Is this to be interpreted as a movement which is purely an expression of accessory muscles of respiration? All movement converges to the hilum, lateral movement at the hilum being about 1 inch. The outer movement is inspiration and the inner movement expiration; that is, the movement from periphery to midlung is that of expiration, while the reverse is that of inspiration. The heart movement may also be seen in some of the pictures. It is for that reason that inspiration and expiration should be taken rapidly, one following on the other.

The excursion of the diaphragm should be observed, and compared with lung movements at various levels. The movement of the diaphragm and bifurcation, which is usually upward and downward, also should be noted; likewise, variations in the appearance of the arch of the diaphragm, which is larger during inspiration than it is during expiration.

Studies in respiration are incomplete unless the ordinary examination of the chest, the bronchoscopic roentgenogram and the fluoroscopic appearance are recorded. The following brief paragraph illustrates some of the observations that can be recorded during a bronchoscopic examination that includes an injection of iodized oil. They will serve in many instances not only as an aid to treatment but as a definite help in estimating the prognosis.

#### OBSERVATIONS TO BE MADE WHILE PREPARING THE PATIENT

While anesthetizing the larynx one may observe the nature and amount of sputum that is coughed up. This may be compared with what is brought up by bronchoscopic aspiration and posture. The rigidity or flexibility of the bronchial tubes as well as the respiratory movements at the carina should be noted, and cultures should be taken. A bronchoscopic diagnosis should then be made. The general condition of the patient up to this point serves as an index as to the amount of iodized oil that should be injected, and the amount of time that can be expended during the balance of the examination. The interval that elapses following the taking of the roentgenograms as well as the activity of the cough reflex, and the amount of sputum raised during the taking of roentgenograms, should then be recorded.

The roentgenograms should then be studied with the roentgenologist, as only thus can complete report be made. Roentgenograms taken with the Bucky diaphragm are usually much clearer and usually give greater detail. Differences should be noted; one should likewise not be satisfied with a single roentgenogram in one position. A series of roentgeno-

## SUMMARY AND CONCLUSIONS

In the living subject, the bronchial tree was injected with iodized oil, 40 per cent, by the bronchoscopic method; in postmortem specimens, it was injected with paraffin. The blood was injected with barium sulphate in gelatin, and its relation to the bronchial tree was considered. The physiology of respiration in the normal and pathologic lung was studied.

Lung abscesses were classified after studies made following the injection of iodized oil.

At various age periods, the appearance of the normal bronchial tree after the injection of iodized oil appears to be constant.

Abnormalities of the bronchial tree are frequent in chronic fibroid phthisis, diseases of the pleura and mediastinum and bronchiectasis.

Bronchial stenosis is often found to be associated with bronchiectasis or pulmonary abscess.

The branched intrapulmonary bronchi and bronchioles are the most frequent sites of bronchiectasis, putrid bronchitis, bronchiolitis and bronchiolectasis.

The bronchial tree after extrapleural thoracoplasty for tuberculosis may undergo numerous changes, and becomes a large tube associated with localized or generalized bronchiectasis at the base. When the bronchiectasis extends to the periphery, methods of collapse should give better results than when the dilatations are basal.

Iodized oil by the bronchoscopic method is an aid and a guide in the selection of suitable cases for the thoracic surgeon, and in the prognosis and treatment. It makes it possible to treat each case individually, and increases the good results obtained by postural drainage.

Ordinary roentgenograms of the bronchial tree are unsatisfactory and often confusing, owing to the fact that the bronchial tree divides frequently and is repeatedly crossed by part of the pulmonary circulation. It fails to give any information as to the site and extent of the disease.

The importance of the accurate interpretation of roentgenograms made following the injection of iodized oil must be emphasized. A positive shadow cast by an injection which cannot be adequately explained on the basis of clinical history, signs, symptoms and a bronchoscopic examination should not be considered. A typical shadow when substantiated by a clinical picture allows of no discussion.

TABLE 1.—Classification of Bronchiectasis

A. CLINICAL

Congenital or Acquired	}	Unilobar or Multilobar
Acute or Chronic		Unibronchial or Multibronchial
Unilateral or Bilateral		Bronchiolar

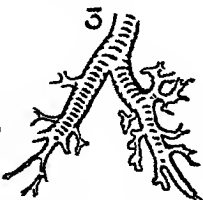
Roentgenologic types based on injection of iodized oil, 40%



Grape



Clubbing



Cylindric



Saccular



Bead Formation

B. PATHOLOGIC

1. Bronchiectasis, chronic infective
2. Bronchiectasis, secondary, due to stenosis, new growth pulmonary fibrosis, etc.
3. Bronchiectasis, dry with hemoptysis
4. Bronchiectatic abscess, acute
5. Bronchiectatic abscess, chronic with bronchiectasis
6. Bronchiectasis, chronic, associated with abscess of the lung
7. Bronchiectasis, tuberculous: A, diffuse; B, local

(1) The grape formation is shown in figure 4; (2) clubbing, in figure 5; (3) the cylindric in figure 6; (4) the saccular in figure 7, and (5) the bead formation in figure 8. A, the diffuse type is seen in figure 9, and B, the local type in figure 10.

The value of such a classification in the diagnosis and treatment of bronchiectasis has been considered by us elsewhere.<sup>9</sup>

As bronchiectasis is so frequently associated with abscess of the lung, the following classification of abscess of the lung, which has already been published, will be again here noted.

TABLE 2.—Classification of Abscess of the Lung

SOLITARY

- a. With fluid level, acute or chronic

This type of abscess is demonstrable by ordinary roentgen ray

- b. Large bronchiectatic abscess, acute or chronic

This type of abscess may be aspirated and will inject with iodized oil, 40 per cent; often it is bilateral, and at times is associated with some other phase of bronchiectasis

- c. Associated with bronchiectasis, chronic

This is the narrow neck type in which expectoration is only overflow; it shows no fluid level, and on injection the abscess area casts no shadow

MULTIPLE—Lung abscesses, chronic

SECONDARY—Those due to tumor and foreign body

TUBERCULOUS

This type may be associated with bronchiectasis, acute or chronic

Metastatic lung abscesses and cyst degeneration are not considered in this classification

9. Ballon, D. H., and Ballon, H. C.: The Diagnosis of Bronchiectasis: Further Studies on the Value of Lipiodol by the Bronchoscopic Method, to be published.



tered. It cannot be stated that it has benefited patients much, but the cases in some of these cases have disappeared from the sputum at least temporarily.

"Chronic bronchitis" has been a convenient term under which many conditions of the respiratory tract have been described. It is time for these conditions to be defined more closely. Injection of iodized oil for outlining of the bronchial tree and bacteriologic examination will both help.

From the medical point of view, the excellent results that can be secured by rest and posture in the earlier cases of every type of septic infection is impressive. Rest may be the best treatment in these cases. Two months in bed may relieve a cough that has lasted many months or even years. Perhaps it is time to begin teaching prevention as well as cure.

Below is an outline of the points to be noted in the differential diagnosis between earlier cases of septic infection and pulmonary tuberculosis.

*Comparison of Septic Infections and Pulmonary Tuberculosis*

	Septic Infections	Pulmonary Tuberculosis
Lesions.....	Usually basal	Usually apical
Sounds.....	Musical rhonchi common Coarse râles	True râles, small, crepitant Coarse râles chiefly in cases in which there is secondary infection
Cough.....	Much at early stages Increased amount in late active stages	Little or none at early stages Variable at all stages
Expectoration.....	Profuse even in early stages Increasingly profuse in late stages  Often bad smelling	Slight or absent in early stages Profuse usually only with secondary septic infection (i. e., tuberculous plus septic) Bad smelling, sometimes with secondary infection
Dyspnea.....	Usual and marked Consistent with good condition Can be dyspneic but not ill Related to extent of lesion chiefly	Less usual and less marked Not usual with good condition Likely to be ill if dyspneic Related to toxemia chiefly
Hemoptysis.....	Less usual Blood streaked sputum more common	More usual Less common
Pleurisy.....	Uncommon	Common
Other Pains in the Chest....	Common, troublesome, basal, less localized	Less common; slighter; often apical; unilateral; more localized
Roentgen-Ray Signs.....	Variable, usually basal Often slight, with gross symptoms (without injection of iodized oil) Iodized oil, as useful as barium in abdominal diagnosis	Variable, usually begins at apex Often gross, with slight symptoms  Iodized oil, useful but not so necessary as in septic infections
Complications.....	Of septic type, appendicitis, mastoid, pneumonia, etc.	Of tuberculous type, tuberculosis in other organs
Course.....	Variable Chronic When chronic less curable	Variable Chronic When chronic more curable
Tuberculin.....	No great help in differentiation	
Examination of Sputum.....		A few negative reports are inconclusive, persevering examination reveals bacilli usually, if present

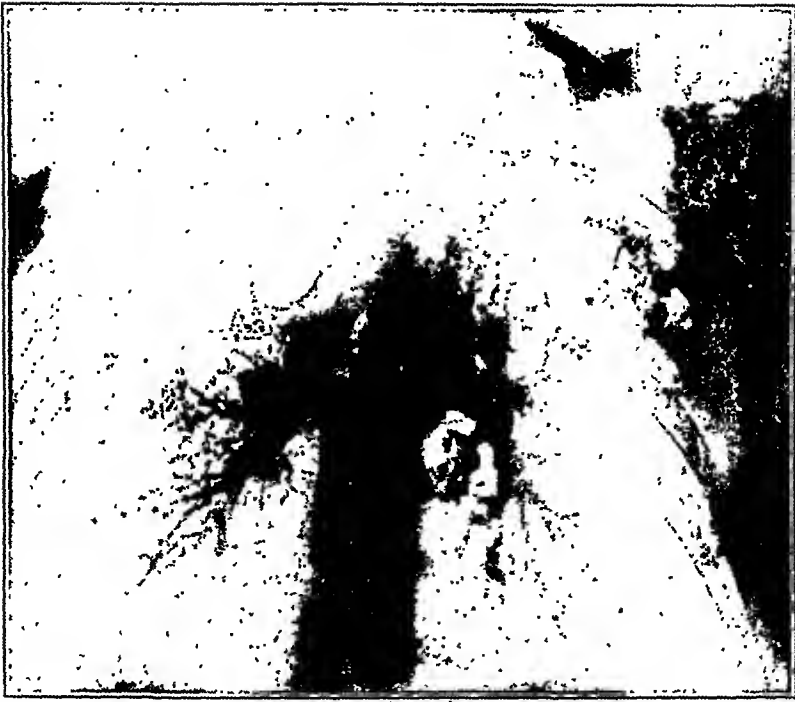


Fig. 6 (case 6).—Bronchiectasis of the cylindric type and clubbing after the injection of 40 cc. of iodized oil; the condition is bilateral. In this type there is frequently an ectasia of the whole bronchial tree.



Fig. 7 (case 7).—Bilateral bronchiectatic abscess, with bronchiectasis of the saccular type, with which there is frequently the associated clubbing. This patient, aged 13, was referred by Dr. Roddick Byers. Twenty-five cubic centimeters of iodized oil, was injected into the bronchi, and repeated in one week without ill effects.

# VALUE OF IODIZED OIL, 40 PER CENT, IN THE DIAGNOSIS OF PULMONARY INFECTIONS

EDWARD W. ARCHIBALD, M.D.

MONTREAL

My interest in diagnosis by the use of iodized oil, 40 per cent, while of course general, has been centered in particular on its value in tuberculous cases: on the one hand, in order to show more clearly than might be possible by physical examination or the ordinary roentgen-ray examination, the pathologic condition in a lung previous to a proposed thoracoplasty; on the other hand, to show the condition in the lung which might explain a lack of complete success years after a thoracoplasty. In addition I shall report a few cases illustrative of its value to the surgeon in nontuberculous lesions.

## REPORT OF CASES

CASE 1.—C. R., a man, who had had tuberculosis since 1919, with repeated pulmonary hemorrhages, had had a thoracoplasty performed two years previously but an incomplete one, the first and second and the tenth and eleventh ribs having been left intact. He had improved considerably, but for the last few months before admission to the hospital, cough and sputum had again become troublesome. The usual roentgenogram showed nothing but a dense, homogeneous shadow. One taken after an injection of iodized oil, 40 per cent, revealed marked bronchiectasis in the lower lobe, and the persistence of some cavitation in the upper lobe. A complete thoracoplasty was performed, the reformed bone and the other ribs being removed, with excellent compression and an excellent clinical effect. Such correction operations frequently are worth while. Parenthetically, it may be said that iodized oil almost always reveals the existence of a bronchiectatic condition in the lower lobe in these old tuberculous cases.

CASE 2.—Miss L. had had tuberculosis probably since 1910. In 1912, she had had fever, had been fatigued easily, and had raised a slight amount of sputum. Since then the disease had been quietly progressive, and when she consulted me there was considerable cavitation in the left upper lobe and slight disease on the right side, apparently quiescent. The roentgenogram after the injection of iodized oil revealed the large size of the cavity. After the injection of the oil, however, she had a febrile reaction with an increase in the pulse rate, which lasted a week. After the subsidence of the fever, I performed a thoracoplasty. The wound became partly infected. In spite of this, I performed the second stage, which was probably an error in judgment. She had a large cavity under the scapula, and I separated the lung extensively both from the vertebral side and anteriorly under the stumps of the ribs, in order to collapse the cavity. This was followed by an acute tuberculin intoxication, which left her extremely weak; moreover, the upper wound suppurated. It is probable that she would have survived, but about the tenth day a serious secondary hemorrhage occurred in the wound, which, in her weakened state, proved fatal in a few hours.

We may also mention that putrid bronchitis need not necessarily be associated with bronchiectasis. We have several instances in which the roentgenogram of the injection showed a normal appearance.

#### EFFECTS OF THORACOPLASTY ON THE BRONCHIAL TREE

It is interesting to observe how such factors as extrapleural thoracoplasty may affect the bronchial tree in a purely mechanical manner. Following extrapleural thoracoplasty for tuberculosis, the bronchial tree

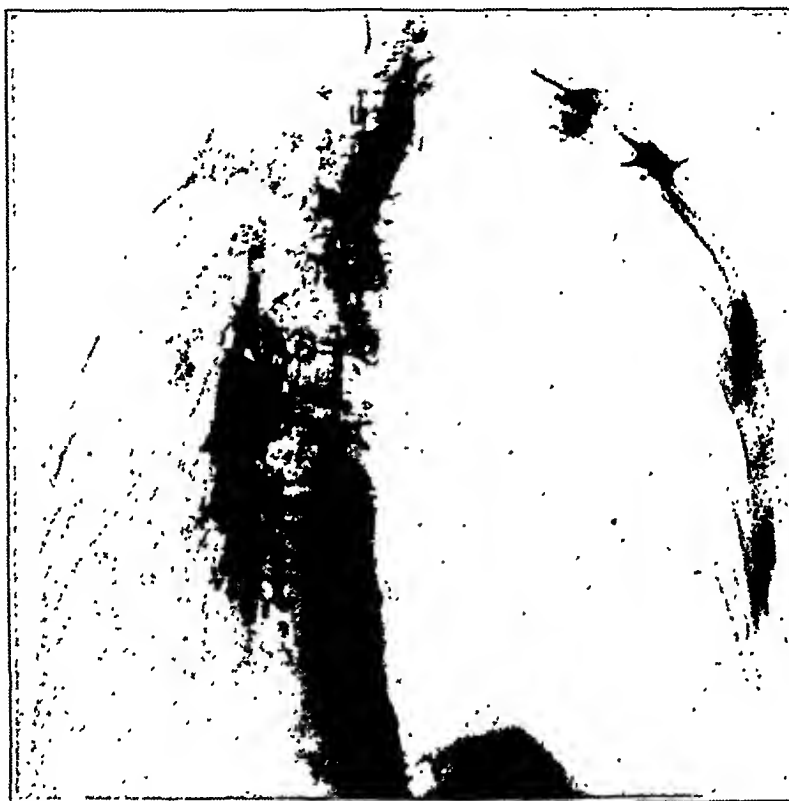


Fig. 10 (case 10).—Tuberculous bronchiectasis of the local type which had persisted following extrapleural thoracoplasty; it was responsible for persistent cough and expectoration. The first injection of 10 cc. of iodized oil was made Aug. 11, 1925.

may become a large tube with dilatations at the base, as in many instances a suitable case of pulmonary tuberculosis for thoracoplasty has an associated basal bronchiectasis.<sup>10</sup> The object of the operation naturally is to collapse cavities, and these are more commonly apical. If the cavity is not too close to the hilum, thoracoplasty usually accomplishes its task.

10. Archibald, Edward: X-Ray Demonstration of Pulmonary Changes in Tuberculosis by Lipiodol Injection, *Canad. M. A. J.* 15:1000-1002 (Oct.) 1925.



Fig. 3



Fig. 4

Fig. 3 (case 4).—Note the homogeneous shadow on the left side in this old thoracoplasty case.

Fig. 4 (case 4).—The iodized oil reveals a fairly large cavity in the upper part of the lower lobe.

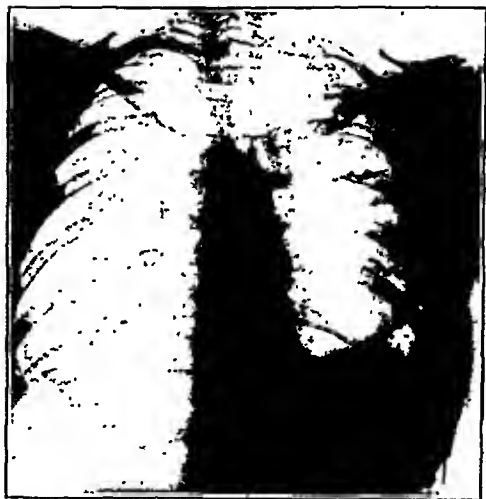


Fig. 5



Fig. 6

Fig. 5 (case 7).—Before injection of iodized oil. Case of nontuberculous inflammation of upper lobe, with distinct cavity just under scapula.

Fig. 6 (case 7).—After injection of iodized oil. Note unexpectedly enormous size of cavitation in upper lobe and slight bronchiectasis in lower lobe.

In studying roentgenograms taken following thoracoplasty, in which iodized oil has been injected, persistent cavities often present an irregular outline. The impression is that pleural adhesions possibly are preventing collapse of the cavity. For this reason more careful consideration than has been given in the past should be given to the amount of pneumothorax which has been attempted before operation, the period of time in which it has been carried out and the nature of the pleural adhesions which may be present and have persisted and rendered further collapse impossible. When these facts are compared with the size and shape of the cavity, it would appear that they should serve as a valuable aid in telling one not only how much rib to remove before a satisfactory collapse can be obtained, but also as to the area that requires the greatest amount of compression. It should also help one to determine whether anterior compression, apicolysis or other means are necessary to produce the desired change in the shape and contour of the cavity and the associated dilatations. The fact as to whether there has been fluid in the pleural cavity which has required frequent aspirations is likewise of importance, and too frequently fails to come into the estimation of prognosis.

One might perhaps ask whether the low vital capacity in many of the persons who have marked chronic cough and expectoration, who show no gross evidence of pulmonary congestion, and who are otherwise in fairly good health, is not in some instances an expression of poor pulmonary ventilation explained on the basis of diffuse fibrosis, in a lesion that is characterized by avascularity. Perhaps, too, the ideal stage at which to operate on a patient with fibroid phthisis is not being sufficiently recognized, and fibrotic changes are waited for too long. The number of suitable cases of pulmonary tuberculosis accompanied by empyema which are allowed to progress until a bronchial fistula develops before intervention is attempted is striking.

The mere fact that the heart is frequently pulled decidedly to the more affected side, and often overlies a cavity with which it is perhaps connected by a broad adhesion, must also frequently be a hindrance to a good result.

It is hoped that the foregoing digression will illustrate the fact that the proper use of such an agent as iodized oil in diseases of the thorax should in many instances enable one to treat each case individually rather than as a type case of a broad group. In chronic cases, in which the patients are poor risks and often can stand little handling, it is hoped that when the chance to use it is presented to them, they may take it. Persistent signs and symptoms will likewise be more adequately explained.

CASE 7.—A nontuberculous abscess of the lung, in which there was enormous cavity in the upper lobe. The injection of iodized oil showed that it was much larger than had been expected. The result of resecting the upper eight ribs was surprisingly good. She soon raised almost no sputum.

CASE 8.—W., a man, had a large chronic empyema following a bullet wound received in the World War. The value of the use of iodized oil in the diagnosis of a pleurobronchial fistula was shown in this case. The iodized oil ran through the fistula and partly filled the empyema cavity. It also demonstrated, usefully, that the lung itself was practically normal, thus eliminating the possibility of a coincident pulmonary abscess. The patient was cured by a resection of the overlying ribs and a plastic closure of the pleural fistulous opening.

#### SUMMARY

In tuberculous cases, iodized oil should be used with caution. A simpler method of injection than the bronchoscopic probably is best because, no matter how carefully and skilfully this procedure is carried out, it taxes the patient's strength more than a simple supraglottic injection.

Injection of iodized oil in old thoracoplasty cases in which the symptoms persist is valuable. Roentgenograms taken after such injections reveal lesions that cannot be demonstrated by any other method.

It is useful at intervals during the progress of a several stage operation, for bronchiectasis or abscess of the lung, in order to estimate the amount and location of the disease that still remains.

#### ABSTRACT OF DISCUSSION

ON PAPERS BY DRs. SINGER, TUCKER, BALLON AND BALLON, STEWART,  
AND ARCHIBALD

DR. FREDERICK LORD, Boston: Experience with the injection of iodized oil has been limited. It seems to me that up to this time it has been of relatively limited value and that some caution should be exercised in its use. In the selection of cases, it is desirable to make the diagnosis without using it if possible. In the abscess cases this usually can be done. There are few cases of abscess, however, in which one does not see more than a dense shadow in the region of the abscess. Much depends on the character of the roentgenogram. An overexposed film or an underexposed film is not as valuable as one properly exposed. In those cases in which the abscess cavity is not clear, the cavity should be drained, the roentgenogram made, and this roentgenogram compared with the previous roentgenogram. In this way one can sometimes outline the cavity. By every means possible the effort should be made to make a diagnosis without the injection of iodized oil. In the films shown by Dr. Archibald, he called attention to the persistent presence of the iodized oil in the lung, and I have noted its presence for months after injection. This may be a disadvantage in the observation of progress of abscess cases in which one is undecided whether to operate. In this group, it is undesirable to have the affected region obscured for a long period by iodized oil. In selected cases, however, iodized oil has been of material assistance. We have been able by its use to determine the site and extent of abscess cavities not otherwise to be found. This is especially true of lesions situated behind the shadow of the heart. In these films, one should notice how frequently the

respond to mere posture, but requires something else in the way of an aid. Bronchoscopy and bronchoscopic methods often supply this want. Each case should thus be considered a law unto itself.

#### INTRABRONCHIAL ROUTE FOR APPLICATION OF MEDICATION

The intrabronchial route should be employed more frequently than it has been in the past for the direct application of therapeutic agents because it disseminates them by coughing. In such conditions as putrid bronchitis, when it is not associated with bronchiectasis, or in the non-sensitive asthmas, it is often of extreme value. In bronchiectatic conditions it is also of value, but it is the frequent aspiration and emptying of these dilatations that produce the best results.

#### CAUTIONS AS TO ABNORMAL SHADOWS AND CHOICE OF PATIENT

We cannot conclude this report on the bronchial tree, in which the value of iodized oil is obvious, without uttering a few words of caution: first, as to the interpretation of abnormal images that are not associated with signs and symptoms, and second, as to the fact that the promiscuous an abscess cavity or dilatation.

A positive shadow that is cast by an injection of iodized oil which cannot be adequately explained on the basis of a clinical history, signs and symptoms should be neglected. Our knowledge as to the interpretation of many of these shadows is still vague. Insufficient pulmonary ventilation, immobilization of the parenchyma or temporarily arrested respiratory movement may be responsible for a shadow that simulates an abscess cavity or dilatation.

No injection of iodized oil should be undertaken until a complete history and physical examination have been carried out. The person who is to give the injection should then not only observe the patient himself but also should discuss the condition of the patient with the attending physician before attempting an injection of iodized oil, and then give it only after deciding that it will be of value. Extremely ill patients should thus not receive injections of iodized oil or the results will cause the method to fall into disuse. In the case of a foreign body, not even the most ardent antispecialist would refrain from having a bronchoscopic examination made.

The use of iodized oil is of undoubted, and promises to be of further, value, if used intelligently. If special methods are used in their proper place, specialization will occupy an even more enviable position than it does at present.



incidental to the method employed. Not long ago I was hurriedly called to an operating room where a careful surgeon had given an injection of iodized oil by injecting it through the cricoid cartilage. Immediately the patient began to cough, causing a hemorrhage. It was not an alarming one, but he apparently was aspirating the blood and coughing it out. The patient's condition was alarming for half an hour. A marked febrile reaction followed and persisted. It will be extremely interesting to note whether lung abscess or bronchiectasis will result. I believe that in employing that type of injection one will get a fair percentage of patients who will develop a reflex spasm with coughing and that the iodized oil solution is going to be aspirated back into the other lung and even into the stomach, so that the use of this type of injection is questionable. I feel that in the use of iodized oil as a diagnostic measure by the members of this society probably not many accidents would occur, but if the method was broadcast throughout the country as a safe procedure and all physicians began using it, I am not so sure that the accidents and the ill effects would not offset the value. I should like to hear from the various members of the number of patients they have seen with ill effects following the injection of iodized oil. I have talked with several of the members who have employed the method, and each one had seen some serious ill effects of the injections. One man mentioned that in injecting the solution the needle was broken off in the throat, and he had great difficulty in getting it out. Such incidents must be borne in mind in encouraging the wide use of such diagnostic methods. The fact that for years bronchoscopic examination has been contraindicated in patients with pulmonary tuberculosis seems to have been forgotten even by members of this society in their zeal to inject iodized oil through the bronchoscope.

I believe that the use of this oil is valuable in diagnosis in vague intrapulmonary conditions. It is, however, a diagnostic refinement not free from ill effects and dangers, and should be reserved for use only in those cases in which it is felt that if the diagnosis is made certain more definite treatment may be given.

DR. FRANZ TOREK, New York: May I suggest that in cases in which iodized oil is injected, after the patient has been placed in the upright and lateral positions, he should be placed on a table that can be turned readily to the Trendelenburg posture? Iodized oil enters the bronchial tree by gravity, and the roentgenograms presented here, for instance, those presented by Dr. David Stewart, show that the iodized oil is found almost exclusively in the lower part of the lung, probably because those injections were made in the upright posture. In the roentgenograms Dr. Singer showed in which he had placed his patients on the side, there was a much better distribution; a large portion of the bronchial tree was shown in the central portion of the lung. But in all the roentgenograms there is a failure to demonstrate the upper bronchial tubes satisfactorily.

DR. CARL A. HEDBLUM, Chicago: In my opinion, the introduction of iodized oil is likely to prove to be one of the most important additions in recent years to the armamentarium in the diagnosis and checking of results of treatment in thoracic surgery. This opinion is based partly on the result of my own experience, partly on my impressions of the reported experiences of others and on the demonstrations made here. It is true that any method can be abused. I believe that the use of it is scarcely warranted when the diagnosis is clear without it. But in the differential diagnosis of disease of the bronchial tree, particularly bronchiectasis, in my opinion, it will prove indispensable. I have studied a series of more than 400 cases of bronchiectasis, in 28 per cent of which it was impossible to determine from the physical observations and roentgenograms whether the disease was unilateral or bilateral. The diagnosis probably was mistaken in many of the

# SEPTIC CONDITIONS OF THE CHEST,

## ETIOLOGY AND DIFFERENTIAL DIAGNOSIS

DAVID A. STEWART, M.D.

NINETTE, MANITOBA

I am not on the program and have no prepared paper, but I have a few slides I can show and add some comments, so that, in the absence of Dr. Stuart Pritchard, the medical side of the problem may not be left altogether without a representative.

The thoracic surgeon is seldom the first, and may be even the fourth, diagnostician in these cases. The first, and usually a poor one, is the man himself. If conditions become serious, he calls the family physician, who, in turn may consult with a sanatorium physician of more specialized experience, and still later the surgeon may be called in. If any such order as this is followed, the surgeon sees the fewer patients with the most severe condition; the family physician a much larger, and, on the average, less troublesome, number, while perhaps most patients are allowed to develop a more or less chronic condition at home. This condition is called chronic bronchitis, asthma or "stomach cough." If the least and the greatest of these bronchopulmonary septic infections were counted, they might be called legion, for they are many. The pyorrhea cure advertisers assure us that "four out of five have it." What might be shown by a careful study of the persons with a chronic cough in any community?

One common cause of these septic conditions seems to be bad teeth and gums and badly cared for mouths. One of the commonest clinical pictures is that of cough, expectoration, debility and bad teeth. The cleaning of the mouth, with a comparatively short period of rest, will work wonders in some such cases. Impressive also are the large numbers in whom cough and expectoration, chronic and increasing, with such general symptoms as debility, and not infrequently with hemorrhage, follow acute respiratory diseases, especially of childhood. A man of 22 has coughed and expectorated since he had pertussis in his first year; others, since they had influenza months or years before; one, since he had measles at the age of 9, and many since they had pneumonia in childhood. The cough-expectoration syndrome dating back to childhood, is common; the patients will state that they have had cough as long as they can remember.

The infections following operations under general anesthesia are well known. In many of these septic infections, spirochetes and fusiform bacilli have been found, as described by Dr. David Smith of Ray Brook, N. Y. In some such cases neoarsphenamine has been adminis-

tion of iodized oil, small *nodules* are clearly visible. The case is a complicated one. I should like opinion as to whether it would be better to leave the tube out or not. The patient is not coughing now. No pus comes from the tube, only mucus. She coughed after the iodized oil was injected and drove some down into the other lung. Of course, mucus or mucopus would not be driven into the other lung so easily. Iodized oil, which is a pure liquid, is easily driven into the other lung. I believe that there is a real danger in using any liquid substance, iodized oil or anything else, in this manner, because it may wash infection from one side to the other.

One word about tuberculosis: I asked Dr. Gehrcke of Brauer's Clinic what they were doing with iodized oil. He said that they were afraid to use it in tuberculosis because they found that it spread the disease; sometimes they did not use it until from one to three months later. There had been some immediate bad results as well. It takes implantation tuberculosis a long time to produce physical signs, and it may be that some of the patients that are not immediately harmed by the iodized oil may show bad effects later. I therefore agree heartily that physicians should be slow to use iodized oil in tuberculosis.

DR. DAVID T. SMITH, Ray Brook, N. Y.: I should like to say a few words in favor of the simplicity of the method Dr. Pritchard described. Dr. Pritchard visited us at the New York State Hospital and demonstrated his method on six patients, subsequent to which I began to use injections of iodized oil. Without any special training in nose and throat work, I attempted to make injections into thirty consecutive patients and succeeded in twenty-five. The method requires no special apparatus other than a laryngeal mirror, a laryngeal syringe and a fluoroscope. One assistant is an advantage but not a necessity. The patients do not object to the procedure. I spray a little cocaine in the back of the throat, largely for psychologic effect. In this series of thirty cases there were no bad effects, although every one of the patients swallowed some of the oil.

DR. JOHN D. KERNAN, New York: One of the physicians in discussing Singer's method of using iodized oil said that he thought a great deal of it; as a bronchoscopist, in a way, I do not value it at all. To a bronchoscopist it is a horrible method. The idea of injecting a definite amount of iodized oil into the lung to go where it happens to go makes me tremble with rage and wrath. On the other hand, I must confess that the roentgenograms are equally astonishing. They are excellent. I am surprised that such good roentgenograms result from such a poor method. I wish that the late Dr. Lynah were here to see how his idea has grown, for I am sure he was the first one to inject liquid opaque substances into the lung in 1920 and through a bronchoscope, in 1920 and 1921. I have not seen his roentgenograms surpassed here. He and Dr. Stewart made roentgenograms six or seven years ago. As I immediately succeeded him at Lenox Hill Hospital, this work is not such a nine-days' wonder to me. The objection to this spilling-in method, I might call it, is that although it shows certain things that are there, it does not show what is missed. Dr. Tucker brought this out well: How does one know that above the dilatations that can be seen there is not a foreign body, a mass of granular tissues, a stricture or a new growth? These things are missed if a bronchoscope is not used. To me an otologist might as well fail to use his mirror and speculums as a lung surgeon or physician fail to use the bronchoscope in these lung lesions.

DR. WILLY MEYER, New York: Dr. Kernan has mentioned the work of the advanced bronchoscopist and the name of Dr. Henry L. Lynah. I also should like to speak of this man who unfortunately now belongs to history. Certainly if any of the, unfortunately, older specialists in this association, next to Dr. Chevalier

Septic infections and pulmonary tuberculosis are hard to differentiate; there are no invariable rules concerning this. The symptoms are the same, but they differ in their manner of occurrence. Diagnosis is made not by adding symptoms to make a total, but by putting symptoms together to make a picture. There are wide variations in the symptoms in both diseases.

you stop to consider it, not every one is using iodized oil. This is a new method in this country. Every one is learning. That is why the members of this society are here. They are here to hear what the other fellow has to say. Every one wants to learn.

If a substance has been used for three or four years, and used extensively, in South America and in France and in England and in Germany, and no deaths or serious results are reported, it must have merit. The use of iodized oil should not be condemned because a few mishaps have occurred; it is one of the best aids we have in ordinary diagnosis.

DR. GABRIEL TUCKER, Philadelphia: Dr. Stewart, speaking of cases of bronchiectasis, mentioned that the condition often followed the infectious diseases of childhood. In reviewing the histories of chronic cases of bronchiectasis in adults, one finds that they began in childhood. The opportunity has been presented to examine many children who have suppurative conditions of the lung following these chronic infections. The good results obtained by use of the bronchoscopic treatment are remarkable. There has been a large percentage of cures in children by bronchoscopic drainage with local medication, and bronchiectasis in later life has been prevented in these patients. I feel as Dr. Kernan does about all blind methods of introduction of opaque substances into the lungs, in cases in which there is no contraindication to bronchoscopy. In our clinics, we use the bronchoscope in tuberculosis unless there are special indications. A diagnostic bronchoscopy is performed and the patient is kept under observation for several days, when a second examination is made and bismuth subcarbonate or iodized oil is introduced through the bronchoscope. The choice of the opaque substance depends on the bronchoscopic and roentgen-ray observations. No unfavorable results have been obtained with this method in either diagnostic bronchoscopy or pneumonography.

DR. DAVID A. STEWART, Ninette, Manitoba: I have nothing to add except to say that in thirty or forty cases in which iodized oil has been given by the supra-glottic method apparently no harm has been done. Dr. Stuart Pritchard of Battle Creek says the same of 1,600 injections by the same method. I believe that physicians should make much greater use of it than they do of the bronchoscope. But it seems to me that there are a great many cases in which iodized oil can properly be given without the bronchoscope. Perhaps some of the children with cough and expectoration Dr. Tucker spoke of might have been cured by rest without bronchoscopy. It is an excellent treatment in the earlier stages.

DR. DAVID BALLON, Montreal: The great value of iodized oil lies in the fact that it permits a differential diagnosis between suppuration coming from the pleural cavity, from the lung and from the bronchi.

There is a man in the service of Dr. Archibald in the Royal Victoria Hospital at present who was wounded in the World War ten years ago. He received a bullet wound which entered in the region of the left nipple and made its exit near the spine. Since then he has been wandering around from sanatorium to sanatorium suffering from hemoptysis and purulent discharge. The diagnosis was lung abscess or bronchiectasis. As he was receiving a government pension he was even accused of malingering. The results of roentgen-ray examination were negative. A bronchoscopic injection of iodized oil was given, and the diagnosis made with absolute certainty that the man has a bronchopleural fistula. Diagnosis had been impossible by symptoms, signs or ordinary roentgen-ray examination. Iodized oil has its greatest value in bronchiectasis. I have seen no ill results from it. I have been using it in treatment for almost seventeen months. More than half of my patients with

Had iodized oil any effect in reducing her resistance before I operated? I am inclined to feel, with Dr. Singer, that it was more likely the strain of the bronchoscopic examination which caused the reaction. In more than twelve cases of tuberculosis in which iodized oil has been injected through the bronchoscope, only three patients have shown a febrile reaction. In two this was not serious and consisted in a rise of temperature to 100 or 101 and an increase in the pulse rate, both of which disappeared in the course of four or five days; but in the third case (case 3 in this article), it continued for nearly ten days, when I considered it wise not to wait longer and performed a phrenicotomy. Immediately after the operation the patient had a further rise of tem-



Fig. 1



Fig. 2

Fig. 1 (case 1).—Before injection of iodized oil. Note homogeneous shadow and lack of detail on left side.

Fig. 2 (case 1).—After injection of iodized oil. The oil reveals extensive bronchiectasis in lower lobe, behind the heart, and it also partially fills the cavity in the upper lobe. On the right side the oil shows a normal lung.

perature and increase in pulse rate, and ultimately died of rapid activation of the process in the good lung. I feel that one must exercise more caution in using iodized oil in such cases, and I believe that I shall have to adopt Dr. Singer's simple method for the tuberculous patient, in order to avoid as much as possible the strain of the bronchoscopic examination.

CASE 3.—The roentgenogram of Mrs. S. shows a homogeneous shadow, with the exception of the cavity at the top. She had been sick since 1920. She had had bronchopneumonia in 1924. A test phrenicotomy was performed. After six days she died of acute tuberculous bronchopneumonia of the good side.

# NONTUBERCULOUS PULMONARY DISEASE

W. F. HAMILTON, M.D.

MONTREAL

There are three classes of persons interested in the correct diagnosis of the nontuberculous form of pulmonary disease, the physician who is the responsible adviser in the case, the friends of the patient and the patient himself. It is true that this community of interest obtains in practically all diseases, but in tuberculosis there is the question of satisfactory treatment, a protracted illness and much time lost from one's occupation in order to effect a cure, to say nothing of other possible results, so that more than ordinary interest attaches to cases in which the question of tuberculosis is raised. The answer is not infrequently difficult.

With this group of three, another may be mentioned, the sanatorium physician to whom these patients with tuberculosis are sent. Reports from various sanatoriums show that patients with nontuberculous pulmonary diseases are constantly being sent to these institutions and constitute from 25 to 50 per cent of the patients admitted. These observations alone compel occasional emphasis on a subject that a prominent internist years ago regarded as old and well recognized. There is need of being constantly reminded of the teachings of the older clinicians, lest their precepts be forgotten. It is on this account that I venture to speak briefly on this somewhat frequently discussed topic.

As sequelae of pneumonia or of bronchopneumonia or of influenza—as well as of pleurisy and of bronchitis, and in many cases in which no such relationship can be traced—European and American writers have discussed different types of chronic nontuberculous pulmonary disease. Feissenger, in 1889, Pfeiffer, in 1893, and Morel-Lavallee, in 1897, described protracted cases of pulmonary disease, including bronchitis and pleurisy following influenza. In this country it would appear that Lord, in 1902 and in 1905, was the first to emphasize the importance of this subject in his report of nineteen cases, in which were included eight patients acutely and eleven chronically ill. Careful microscopic studies were combined with physical examinations. In seven of the nineteen cases, tuberculosis was suggested by cough, and physical signs in the chest were persistent for months and even years. In three cases, the lung apices were involved. Lord found influenza bacilli in the sputum of these patients for long periods. He says that the subjects of such infection, who are continually harassed by a troublesome cough, more or less abundant sputum, dyspnea, occasional rises of temperature for brief periods, localized bronchitis and doubtful or certain signs of consolida-

Whether the iodized oil which penetrated the less diseased side had any effect in starting the acute tuberculous process is a question. It is almost impossible to say whether it had or not, but this case suggests the necessity for caution. It is much more likely, of course, that the slightly active disease on this side was aggravated by the operation. In any case, that activation may have been assisted by the previous injection of iodized oil.

CASE 4.—Miss D. consulted me in 1922 concerning a lesion on the left side. The left lung had a large cavity at the apex. She was greatly improved by a thoracoplasty. Symptoms recurred in two years, and the cause of this recurrence was revealed only by the injection of iodized oil, which showed a new cavity in the lower lobe.

I think that iodized oil is valuable in estimating what lesions remain. By stereoscopic examination the lesion can be localized as near the hilum or near the periphery. The question is, What can be done for



Fig. 7 (case 8).—Case of chronic empyema. After injection of iodized oil. The oil shows up the fistulous tract in the pleura and a partial filling of the empyema cavity; it also demonstrates that the underlying lung is normal.

such a lesion? Should one resect more ribs? I leave it at that; but the point is that only by means of oil injections can one get an idea of the problem to be faced.

CASE 5.—Two years ago, after a total thoracoplasty, Mrs. D. returned with an aggravation of symptoms. The cavity, which persisted, was not visible in the usual roentgenograms, but showed in the roentgenogram made after the injection of iodized oil.

CASE 6.—Mrs. McI. was a tuberculous patient with a cavity in the left upper lobe. I did not know that this was so large until after the injection of iodized oil. Good filling was secured in the cavity of the upper lobe. This can be accomplished only by careful posturing. The roentgenogram showed the large size of the tuberculous cavity. The patient improved after thoracoplasty, and I had a letter recently which stated that she raised almost no sputum.



also is a fairly common disease, and one that we associate with an early tuberculous infection. The idea prevails in the minds of many physicians that influenza predisposes to tuberculosis. If one takes the total of these three impressions, whether or not they are sound opinions, one finds a reason for suspicion in all cases in which there is cough, expectoration; weakness and occasional short runs of light fever. If one adds to these the results of observations carefully made, pain in the chest, râles, apical signs and shadows of increased density in lung areas, one has good grounds for suspecting such cases as being due to tuberculous infection; hence, there is great need of care in differentiation.

To this already long list one must add still other features suggesting tuberculosis. Reference is made to blood in the sputum, actual hemoptysis, and the false or mistaken interpretation of roentgenograms. Hemoptysis has been observed in nontuberculous disease, and a few patients have returned from the roentgen-ray department with reports of chronic or active tuberculosis. As so many of these suspected cases follow influenza and the history of influenza is thus likely to bias the mind of the inexperienced in medicine, it is of interest to quote Fishberg on this traditional relationship:

Contrary to the teachings of writers of previous generations, the recent epidemic of influenza has shown that this disease is not etiologically related to tuberculosis. Of the hundreds of cases which have come under my observation during the past year in which cough, expectoration, fever, etc., have persisted after an attack of influenza, only one turned out to be tuberculosis. The pulmonary sequelae of influenza are hardly ever tuberculous in nature.

The physical signs in nontuberculous pulmonary disease are those of bronchitis of one or a part of one lower lobe or even of both lower lobes; rarely are these signs found in the upper lobe. The signs are persistent yet variable. Later the signs of emphysema may develop. The roentgenograms show varying degrees of fibrosis. Constitutional symptoms of tuberculous infections are in the main absent, while tubercle bacilli are constantly absent from the sputum. The diagnosis on the basis of bacteriology has been urged, but this is obviously extremely difficult.

As I wish here to comment on the late results of nontuberculous lung inflammation, I will report illustrative cases.

#### REPORT OF CASES

CASE 1.—A Jewish pedler, aged 45, had periodically frequented my service in the outpatient department of the Royal Victoria Hospital for several years. He also had been a patient in the ward on two or three occasions. The onset of his illness had appeared to date from an attack of pneumonia fifteen years before, from which he had made a tardy recovery. As this illness had occurred in Russia, details were unavailable. The patient thereafter was subject to frequent "colds." After coming to Canada, he had carried his merchandise about the country, walking the greater part of the time.

iodized oil overflows from the side in question. I cannot believe that it is desirable in tuberculosis to flood the respiratory tract with any fluid and allow the contents of the bronchi to mix with that fluid to uninfected parts of the lung. In one nontuberculous case of lung infection pneumonia developed on the opposite side from that in which insufflation was performed. How far the iodized oil, which had been introduced into that side, was responsible cannot be said; fortunately, the patient recovered.

Dr. A. L. Lockwood, Toronto: I have had a limited experience in the use of iodized oil—only thirty odd cases in human beings and eighteen or twenty instances in rabbits and dogs. I have been prejudiced against it because of some unfortunate experiences in these cases. I was called to operate on the first patient I saw who had received an injection of iodized oil, for lung abscess: the picture was exactly the same as that shown in one of the slides here. I was impressed by the picture of abscess of the lower lobe. In spite of the fact that the patient was extremely ill, I suggested observation for some days to determine what course the condition was going to take. Following the injection of iodized oil, the temperature and pulse were maintained for three or four days, and then were elevated considerably. The injection had been made through a bronchoscope, which may have increased the fever apart from the iodized oil. On the seventeenth day the roentgen-ray examination was repeated. There was still a certain amount of shadow showing where the abscess was supposed to have been. However, the patient's condition was such that I suggested not operating for a while longer. The next day the patient's physician injected 30 cc. of iodized oil, and the peculiar shadow did not fill. I have seen three similar instances of that in this group. I think Dr. Phillip has a suggestion that may be valuable: that in some cases the iodized oil has run into the stomach and thrown this shadow, which it was thought was caused by iodized oil, into the lower lobe. I should not be surprised if this were true. One instance in a rabbit might have been the same. On the whole, my attitude in regard to the use of iodized oil is that unless I had a serious case and was going to get some real benefit from its use, I should not want anything like iodized oil put into my bronchial tree. If there was a doubt as to whether I had an early bronchiectasis or some vague type of lung abscess or early tuberculosis, I should prefer to go to a sanatorium for a long trial of sanatorium treatment. I would go to Tuscon, Ariz., for a year or two and see what the dry climate and heat would do rather than take the chance of having iodized oil used and having the condition aggravated.

In the case of lung abscesses I am inclined to agree with Dr. Lord that with repeated stereographic roentgenograms, taken obliquely and laterally, and after emptying the abscess, a positive diagnosis is likely to be made in those cases. I think it has been definitely shown that the bronchoscope should be used as a matter of routine in all cases of vague bronchial disturbances. The bronchoscope causes recurrence in a certain percentage of patients, so that it is difficult to say whether the iodized oil adds to this condition.

I had thought that the proper way to make injections of iodized oil was through the bronchoscope, but I am pleased with the suggestion of Dr. Singer, and I have tried the method on some rabbits. What happened in these rabbits was this: With the first injection given, there apparently was little reaction. Necropsy was performed on some of these, and the iodized oil solution still remained in the bronchioles, but little evidence of irritation was seen. But with a second or third injection a definite bronchiectasis can be produced. I should like to hear the unfavorable reports of the use of iodized oil, how many accidents have happened in its use, not only from the reaction attributed to the iodized oil itself but

the lesion now practically ten years quiescent? In answer to the first question, it may be stated that the character of the onset was against the view of an acute pulmonary tuberculosis. The condition began with pharyngitis, laryngitis and tracheitis, with constitutional symptoms and pulmonary signs after a few days, which is a rare sequence in pulmonary tuberculosis but a common one in a catarrhal bronchial infection which later shows definite signs of bronchopneumonia. The second question is to the way in which this acute bronchopneumonic process would affect the lesion now practically ten years quiescent. At the present time, four months later, her physician says that she is as well as she was two years ago.

CASE 4.—E. W., a woman, aged 40, had intercurrent nontuberculous pulmonary disease of nine months' duration associated with the first attack of pernicious anemia. The patient was admitted to the Royal Victoria Hospital in December, 1923, complaining of cough, expectoration, loss of weight, shortness of breath, pain in the left side of the chest, weakness and indigestion. For the last nine years she had had an indefinite history of nasal catarrh and colds. In May, after the extraction of several teeth, she had developed pleurisy on the left side and shortly after a similar condition on the right side, accompanied by cough and weakness. She had been sent to the mountains for recovery. While at Sainte Agathe another "cold" had developed, and occasionally she had noticed that the sputum was blood streaked. There was no history of any serious illness preceding this. She had worked as a housemaid, and was constantly troubled with "indigestion." For thirteen years varicose veins had bothered her, but they had compelled her to give up work only recently.

The patient was thin and pale. She was slightly febrile while in bed, the temperature falling low and showing a wide range. The pulse rate ranged from 80 to 100, even at rest. Cough and expectoration were present. The chest was long and narrow, the note slightly impaired over the apex on the right; prolonged expiration and fine crepitations were heard over the upper lobe and at the apex of the lower lobe on the right. Later, however, signs of bronchitis became more evident. Dry and moist râles were heard both anteriorly and posteriorly over both lungs, yet they were always more marked over the right and toward the apex. At the left base, the percussion note was shorter than at the right.

For fully eight weeks the temperature was febrile and signs of bilateral respiratory disease were noted throughout. The sputum which was examined frequently, was negative to tests for tubercle bacilli. The blood and spinal fluid gave no Wassermann reaction. Roentgenographic examination made on admission showed the bronchial tree intensified toward both apexes and bases. Mottling at the right base was suggestive of tuberculosis. This view was modified a month later, and the modification was confirmed three months later.

For several months this patient was suspected of having pulmonary tuberculosis, yet she failed to show the undoubted clinical evidence. Investigation of the blood and of the nervous system, as well as of the gastric contents, shortly after admission enabled us to say that she had profound anemia and subacute combined sclerosis with achlorhydria. In short, a diagnosis of pernicious anemia was made. After three months in the hospital, the fever subsided, the pulmonary signs greatly diminished, the anemia improved and the patient took on considerable weight, although the condition found in the nervous system remained practically unchanged.

36 per cent of cases judged to be unilateral and in the 36 per cent diagnosed as bilateral, in spite of the fact that the disease in most of these cases was of advanced grade.

I recall one case in particular in which the patient was raising upward of 100 cc. of sputum. The combined diagnostic facilities of the Mayo Clinic were not sufficient to establish which side the pus came from, and bronchoscopy left the matter more or less in doubt. This was, perhaps, due to the overflow to the other side. In 36 per cent of cases the diagnosis was unilateral and in 64 per cent it was bilateral. No doubt, from the facts brought out, we were wrong in a considerable number of cases as to the causes involved. It seems certain that early cases and those of the dry type described especially by French writers have been in large part overlooked. Large numbers have been wrongly diagnosed as cases of tuberculosis. I have had little experience with the method in cases of tuberculosis, and I should not want to make any statement as to its possible harmful effect in that condition. It may prove of considerable value in checking the result of operations, particularly thoracoplasty and the cautery extirpation of Graham, as Dr. Archibald has just mentioned.

As to the method, in the Mayo Clinic we have used the transtracheal route, a little local anesthesia, puncturing the cricothyroid membrane with a needle which is attached to a rubber tube so as to allow for movement of the patient without breaking the needle, and we have not had any bad effects either at the time of injection or later. We have been able to differentiate unilateral from bilateral bronchiectasis with certainty in cases in which we would not have been able to do so without the use of some contrast medium. We have also found it useful in studying cases of empyema with and without bronchial fistula. In a case of pulmonary tuberculosis in which the roentgenogram showed an annular shadow, we were unable to satisfy ourselves as to whether or not we were dealing with a cavity. The injection of iodized oil demonstrated the fact that the annular shadow is not due to a cavity and also shows the pressure of some bronchial dilatation.

A young boy had a history of cough with sputum, loss of weight and fever, but without any bacilli having been found in the sputum during a period of two or three years' observation elsewhere. The diagnosis with which he came to the clinic was abscess of the lung or empyema of the apical regions, with a bronchial fistula. We demonstrated a pleural cavity at the apex. In order to establish whether it communicated with a bronchus, we injected iodized oil into the trachea. Roentgenograms then showed the pressure of the fluid in the cavity, proving the presence of a bronchial communication with it. Later, tubercle bacilli were found in the sputum.

DR. HOWARD LILIENTHAL, New York: A woman had had a complicated abscess of the right upper lobe for a year and a half following an operation on her nose. It was a putrid case. All measures had been tried—bronchoscopy lavage included—and when I came to operate I saw why washings had failed. It was because the pus was inspissated like putty. I operated on her rather high in the axillary line and succeeded in emptying the abscess and producing a good sized bronchial fistula. The patient did well, and the roentgenograms showed no cavity. I wanted to know whether it would be wise to take out the tube and allow the bronchial stoma to close, which it seems inclined to do. Dr. Lewis Gregory Cole and I placed this patient with her head low and injected iodized oil into the bronchial stoma.

Before injection the roentgenogram showed that there was some iodized oil in the lower bronchus which had been there for more than six months, showing how long the oil remains. In the roentgenograms taken after the injec-

## ABSTRACT OF DISCUSSION

DR. W. S. LEMON, Rochester, Minn.: In the survey of the cases that have come under my consideration, there seems to have been a certain order of events. The patients either were so desperately ill that they died quickly, within as short a time as twenty-four hours, and their lungs then were found to be not pneumonic but in a prepneumonic stage without consolidation, wet and dripping with blood, or those who had a little more resistance, or whose infection was less virulent, developed a bronchopneumonia that was so widespread that it became of the pseudolobar type. These patients, because of the oxygen unsaturation, usually were dyspneic and most of them died. Then a third group appeared which we know had definite bronchopneumonia. A larger proportion of patients survived. In those who lived long enough, complications appeared with intrapulmonary abscess formation, or with both intrapulmonary formation and empyema, and frequently it was possible to demonstrate the fact that the empyema was secondary to a subpleural abscess. Such patients are likely to have pleurisy, because almost invariably in diseases of the lung, whether acute or chronic, the pleura is affected to a greater or less degree. Finally, there was a group of patients who through the accident of virulence or of their own strength were able to overcome the disease to the extent that finally they suffered from only what was known as unresolved pneumonia. I think the term "unresolved pneumonia" should be used with a great deal of reservation, because I think it seldom occurs. But sometimes the alveoli which usually expand fail to do so, and then the lungs are subject to this type of infection which remains for years. From six months to a year following these epidemics, an increasing number of patients who had the disease known as nontuberculous lung infection presented themselves at the Mayo Clinic. Nontuberculous lung infection, it seems to me, has proved as time has passed to be the beginning of a bronchiectasis, because in bronchiectasis three things are usually necessary: infection, stenosis and inflammation. Infection was implanted and chronic, and it could be shown by examination of the sputum to be continuous. Stenosis is more difficult to explain, but two conditions can, perhaps, be included as being explanatory of it: first, the enlargement of the tracheobronchial lymph nodes, and, second, kinking of the diseased bronchi. The inflammation that remained and the enlarged glands or stenosis promoted secretion and cough, and the forced inspirational cough together with the absence of the usual elastic support to the bronchi, as well as the damage to the wall of the bronchus itself, permitted the appearance of estasis. So that in greater or less degree, sometimes with the condition impossible of diagnosis other than as chronic bronchitis, there were patients who had a productive cough over long periods of time; this was recurrent with each successive infection, with râles of different characters, usually in the bases of the lungs. Such a picture has been presented so many times that it seems to me that chronic nontuberculous infection is per se beginning bronchiectasis.

DR. FREDERICK T. LORD, Boston: Dr. Stewart has already alluded to the tendency to discard the term "chronic bronchitis," and it is fair to say that this diagnosis is seldom justified as an explanation of chronic cough and expectoration. The most common cause of chronic cough and expectoration is cardiac decompensation and then in order of frequency come inflammatory pulmonary processes and uncomplicated chronic bronchitis for the most part only as a manifestation of bronchial asthma. In bronchial asthma a toxic bronchial disturbance may persist for long periods without giving rise to changes elsewhere than in the bronchi.

Jackson of Philadelphia and Dr. Yankauer of New York, has advanced this branch of medical science, Dr. Lynah has done so. In Boston at a meeting of the American Medical Association six or more years ago, he showed roentgenographically for the first time, before the section on laryngology, the results of his carefully planned injections of bismuth oil into the bronchial cavities.

The advantages that bronchoscopists offer for diagnosis and treatment when they do their work carefully should not be overlooked. If it is made a rule to ask their help, much better operations will be performed on the lung. Sometimes it is possible to diagnose conditions the existence of which would not have been known if injections of the oil had not been made. Dr. Lynah and his specializing colleagues were and are able to tell from what lobe or lobes the pus is being discharged, without jeopardizing the patient's life. In the hospital of which I am a member of the staff, there was only one case among many hundreds in which bronchoscopy was used in which for some unknown reason the patient suddenly died of shock while on the table—not from subsequent pneumonia. Of course, all surgeons have seen severe reactions after bronchoscopy. These are to be expected in conditions of inflammatory origin in the lung after local instrumentation. If I had a case in which I wanted to use iodized oil, in spite of Dr. Singer's ingenious method I would rather not have the oil instilled into the trachea. The bronchoscopist, under the guidance of his eyes, can introduce the oil into the place he wants it and nowhere else. That must prove the safest method for the patient. Guidance by the eyes has greatly advanced the therapeutics of disease conditions of the lung as far as diagnosis and conservative treatment are concerned.

Dr. A. L. LOCKWOOD, Toronto: I distinctly want it understood that I had no idea of advocating the abandonment of the use of the bronchoscope for iodized oil. I simply want to congratulate Dr. Singer on his method. If such a simple method can be used to get such excellent roentgenograms, it should be approved.

Dr. J. J. SINGER, St. Louis: I stated definitely that those who used the bronchoscopic method are people who know how to use it. I do not know how to use it; so I had to use another method. It would not be fair to let this symposium end with a comparison between the use of the bronchoscope and the use of iodized oil, in lung mapping. That is not being discussed, only the methods of using iodized oil. Various physicians have shown various ways of introducing it and the different ways in which they have made their diagnoses. The bronchoscope will do what iodized oil cannot do. Only the larger bronchi can be directly visualized. The bronchoscopic method of introducing oil shows more iodized oil spill-overs in roentgenograms than occur in just placing the patient as shown in my roentgenograms. If a roentgenogram is the only thing desired, one would not use a bronchoscope in the patient when making a roentgenogram. Why make roentgenograms at all? One may take a bronchoscope and look. For the sake of argument, I would agree that there is nothing better than direct inspection of any cavity. When conditions make that impossible, physical signs are used. But a continuation of this subject would introduce a discussion of bronchoscopy. There are five bronchoscopists in the hospital of which I am a member of the staff.

What is the value of iodized oil? A picture is painted that the operator thinks is there. His imagination may go off on a tangent, but just as soon as he knows what to "paint" he does not need 20 or 30 cc. of iodized oil; sometimes 5 cc. will do. I will say that it is as good for localizing as a bronchoscope. One can put it in the upper lobe or the middle or the base. There is no doubt that the oil can be put in the upper almost as easily as in the lower lobes. When

this group of nontuberculous pulmonary infections, internists believe that there are certain ways in which this can be done in the absence of tubercle bacilli. In the first place, the evolution and grouping of the symptoms in the tuberculous cases is different from those in the nontuberculous cases, is an important point to consider in differentiation. Any case in which there is a sudden hemoptysis is probably tuberculous, and those cases in which the hemoptysis is intercurrent with profuse and abundant expectoration may or may not be tuberculous. Cases of primary pleurisy are most probably tuberculous. Cases in which there are signs of the disturbance toward the apical region are probably tuberculous. I say toward the apical region because it should be appreciated that pulmonary tuberculosis begins in the region immediately below the apex. Chief reliance may be placed on the roentgen-ray appearances, and any case in which on roentgen-ray examination one finds a finely or coarsely mottled increase of density above the anterior portion of the third rib is probably tuberculous.

DR. WILLY MEYER, New York: It was illuminating to hear Dr. Hamilton state that from 25 to 50 per cent of those presenting themselves because there is a likelihood of their being tuberculous are nontuberculous. In 1914 I read a paper on bronchiectasis before the meeting of the American Surgical Association at the time of its joint session with the International Congress of Surgery in New York. This was at the beginning of the treatment of bronchiectasis. In order to define clearly, I said that bronchiectasis is a disease of the bronchial tree, not of the pulmonary parenchyma. I knew that anatomically this was not absolutely correct. I have been severely criticized by a New York colleague for that statement. It was therefore interesting to me to hear today emphasized again that bronchiectasis is to be considered a disease of the broncho-pulmonary system.

I hope that it will not be thought that I am partial to bronchoscopy, but I feel that, when treating protracted conditions of inflammation of the lung, if the internist would work with the bronchoscopist he would secure improvement or cure in a number of cases more quickly. In this respect I recall one patient who was treated by the late Dr. Lynah. I diagnosed the case chronic bronchiectasis and referred the patient to him for intrabronchial therapy. It was surprising to see what was accomplished in the case of this girl, who every little while had had a recurrence of fever, increased sputum and other symptoms. The patient was at last so much improved that she considered herself well. She was an Irish girl, and much against our better judgment she returned to Ireland. There she soon began to ride the bicycle, dance and help with haying on the farm. She enjoyed life as others do for more than a year and a half, when she suddenly was taken seriously ill and died. Death may have been due to metastatic brain abscess with suppurative meningitis; this not infrequently has been found complicating chronic bronchiectasis. I wrote to the physician in Ireland, but could not learn the real cause of death.

The procedure with these patients who suffer from nonspecific chronic suppuration of the lung should be one of cooperation. Internist and surgeon examine and with the help of the laboratory make the diagnosis. Then the patient is referred to the roentgenologist for a refined diagnosis. After this the patient with acute, subacute or chronic condition is referred to the bronchoscopist. If he decides to treat the patient, the surgeons allow him to see what he can accomplish by means of intrabronchial treatment. A number of these patients were cured by bronchoscopic treatment. In view of such experience, is it not a duty to cooperate in these cases? Naturally, the bronchoscopist cannot cure every patient; he gradually refers some patients back to the surgeon.

bronchiectasis have been treated in tuberculosis sanatoriums. After treatment bronchoscopically with iodized oil they have been able to attend to their duties.

One of Dr. Archibald's patients, a student with bronchiectasis, who came from Washington, received bronchoscopic treatment from Dr. Birkett and is now able to take a course at the university. It has been possible to visualize associated bronchiectasis with pulmonary tuberculosis. Furthermore, iodized oil has a definite therapeutic value in bronchiectasis. Two of my patients had bronchiectasis for a great number of years. I have given them injections of iodized oil, and cough and suppuration have diminished. They are feeling and sleeping better. One man who has received bronchoscopic treatment for a number of years has gained 40 pounds (18.1 Kg.) in weight. One girl treated in the outdoor clinic has gained 17 pounds (7.7 Kg.) in five months; she received bronchoscopic treatment combined with iodized oil.

The originators of the method have been internists and consequently have had to use other than bronchoscopic methods. But I firmly believe with Dr. Willy Meyer, Dr. Kernan, Dr. Tucker and others that in the future the best results in diagnosis will be obtained by the bronchoscopic method.

Dr. Scrimger operated in a case of lung abscess. The abscess was adequately drained, but for some unexplained reason the patient was not doing well. He asked me to make a bronchoscopic examination. I found the left main bronchus blocked with granulations. Snippings were taken and iodized oil was then injected. The pathologic report was primary carcinoma of the bronchus. Unless an abscess cavity is aspirated, it will not be possible to fill it satisfactorily. Iodized oil has been of value also in the diagnosis of abscess of the lung. In some of these cases in which the abscess cavity is filled, the iodized oil stops short and leaves a silent area.

There will always be ill effects when the oil is injected when the patient is moribund. A patient with acute pneumonic phthisis was referred to me to be given injections, with the obvious results. These patients should never receive injections. After treating this patient, a few months ago, I was asked to make a bronchoscopic examination on a person who was moribund. I examined the larynx and found a complete left recurrent paralysis. I refused to examine him unless the attending physician, who requested the examination, was present. As he was not present, the examination was postponed. The patient died that afternoon.

In regard to the different methods, all except the bronchoscopic are blind methods.

DR. EDWARD ARCHIBALD, Montreal: In no other society could one hear so wide an authoritative expression of opinion on this new method of diagnosis as in this society. Men are gathered here who are particularly interested in the refinements of diagnosis, who are keenly alive to all that is new, and who probably represent the majority of those who are using iodized oil for this purpose at this time. In that sense I think we may congratulate ourselves on this opportunity for exchanging ideas.



mere expansion by inspiratory effort. Dr. Meyer spoke of meningitis as a fairly common complication of suppurative disease of the lung. I did not know of this pathologic sequence, and I am interested to hear that it occurs primarily without brain abscess. I did know, of course, that bacterial emboli and multiple abscesses of the brain are common in this disease.

DR. NATHAN W. GREEN, New York: Some years ago I conducted a series of experiments in the physiologic laboratory and in the course of the experiments I tried to raise the intrapulmonary pressure, in a simple way, by blowing into a tube connected with a manometer. I found that the positive pressure could be raised to 60 mm. of mercury. According to Donders the normal negative pressure in the pleural space in the human being is 7 mm. of mercury. So I think that, as Dr. Lilienthal says, the positive pressure exerted by the spasmodic cough would have more to do with the dilatation of the impaired bronchial tree than the forced inspiration as suggested by Dr. Lemon.

DR. J. J. SINGER, St. Louis: I agree with the other speakers that unresolved pneumonia is really not pneumonia. In most instances there is an inflammatory reaction in the lung which is pneumonitis rather than pneumonia. This pneumonitis may manifest itself in the form of abscesses that may show only a small ulceration while the induration around it may extend probably 3, 4 or 5 inches (7, 10 or 12 cm.). Here and there, there may be more breakdowns, and this breakdown represents what has been termed a carbuncle in the lung. I think that that description would fit in with many of the so-called cases of unresolved pneumonia. I have always felt that the bronchial tubes were nothing more or less than drainage tubes that carry the air into the pulmonary alveoli and send it back; that they are resistant to infection and bronchitis is really not the case. They exude pus from the lung rather than from their own walls. Infection of the bronchi is rare. In dogs one can put bacteria on the mucosa of the bronchial wall and get no infection. It certainly must be the same in human beings who bring up a large amount of pus, with rarely an increase in temperature. They are merely the drainage tubes. The inspiratory element has a part in the development of bronchiectasis, and so has the cough, but neither in itself produces bronchiectasis. There must be weakened extrabronchial tissue that has become infected and formed a sort of carbuncle. This weakens the walls not of but around the bronchi or the tissues around the bronchi, which form the structure around the bronchial tubes. When this tissue breaks down, ulcerates and is infected in these recurrent attacks of pneumonitis, a weakened wall around the bronchi results, and the deep pressure produced by taking deep breaths will eventually push the bronchi in this manner.

DR. DAVID T. SMITH, Ray Brook, N. Y.: I should like to speak of the bacteriology of chronic nontuberculous pulmonary diseases. I would urge members of the association in choosing men to diagnose a case to include a bacteriologist with the roentgenologist, the bronchoscopist and the internist. In chronic nontuberculous infections of the lung there are probably many agents at work. The sputum in all these cases should be examined, and when bronchoscopists are available, I suggest that the bacteriologist examine material collected directly from the lungs. When the bronchoscopist is not available, good specimens can be obtained by brushing the teeth thoroughly several times with toothpaste, rinsing the mouth with a sterile mouth wash, then washing the sputum through several solutions of physiologic sodium chloride solution. The bacteriologic examinations should be made from the central portion of this washed sputum. Some of this material should be examined when fresh, unstained, and some should be examined in 10 per cent sodium hydroxide solution. The sodium

tion, are frequently thought to have phthisis. This is particularly true of the protracted acute or the chronic cases. Pal<sup>1</sup> states that he has observed several instances of catarrh of a pulmonary apex in patients showing disease of the nasal passage. Disappearance and reappearance of the râles run parallel with the condition in the nares. It would scarcely be profitable although interesting to follow the historic aspect of this subject further. Suffice it to say that comprehensive contributions to the literature are being made from time to time, bringing about a clearer understanding of this important subject.

The pathologic lesions in the chronic cases are practically those of bronchitis and fibrosis with bronchiectasis and areas of bronchopneumonia varying in size. The pleura is involved in many cases and bronchial adenitis undoubtedly exists, while more or less widespread emphysema is induced. Lord, who had little opportunity to study the pathologic material in his cases, advanced the theory that small patches of the original bronchopneumonia broke down into minute abscesses which discharged into the bronchi, inducing a chronic bronchitis. Recently, MacCallum's observation on pneumonia following measles in soldiers showed that there was a rapid organization of the inflammatory exudate involving alveoli, bronchi, interlobar septums, the adventitia of the blood vessels and the lymphatics. If these changes were found in the dead, doubtless to a less extent, i. e., in smaller areas, such lesions may induce changes more or less permanent in the lung of patients who are recovering. This would account for at least a few cases in the group under discussion. Fibrosis, emphysema and bronchiectasis, which result from the changes described, are promoted to a large extent by superimposed infections, more or less acute, with the various forms of streptococcus and staphylococcus and the influenza bacillus.

Klotz has pointed out that the end-results of the pneumonic process in influenza are far more complex and indefinite than in lobar pneumonia. From his observations in the Pittsburgh cases during and after the epidemic of 1918-1919, it would appear that after influenza the lungs are damaged in proportion to the extent to which purulent pneumonia is associated with capillary thromboses, organic destruction, abscess formation and reparative processes. In some instances these areas may be so small as to pass unnoticed, while in other cases the process may be so widespread as to compel attention by both symptoms and signs.

#### DIAGNOSIS

Tuberculosis is the most common cause of chronic pulmonary disease, and the history of tuberculosis in a family is common when one surveys the intimate as well as the remote history of a patient. Pleurisy

1. Pal, J.: *Med. Klinik* 20:1726-1727 (Dec. 7) 1924.

bronchial condition, and the condition of the heart overlooked. I think that this is a frequent failing which is unnoticed, and which causes that symptomatology called chronic bronchitis. The emphasis laid on cooperation by Dr. Meyer is important. That ideal is constantly being more closely approached. In respect to bacteriology, I made one remark which I repeat now, that from the standpoint of bacteriology the diagnosis is obviously difficult. I agree with Dr. Smith in his plea for better methods of diagnosis. In hospitals, a large staff of well trained bacteriologists is required, and this takes money and time; whether such expenditure will be rewarded remains to be seen. I believe that the end is worthy of it.

Cough, expectoration and occasional hemoptysis were his chief complaints. The pulmonary signs corresponded to those of chronic bronchitis, with many fine râles over both pulmonary bases. The heart showed no valvular lesion. The sputum was free from tubercle bacilli on many examinations, and as hemoptysis was regarded at that time as significant of pulmonary tuberculosis, elastic tissue was looked for frequently, with equally negative results. Constitutional evidence of toxemia was absent in this patient. He was not emaciated. The roentgenograms showed increased detail along the bronchial tree and greater density in the hilum of each lung. In short, bronchitis and fibrosis were the chief pathologic changes noted.

Several years later, the patient showed increasing dyspnea with cyanosis and marked signs of emphysema, which are the natural results in many patients with this history.

CASE 2.—L. C., a woman, aged 48, was admitted to the hospital, Dec. 1, 1924, for sore throat, cough and expectoration, loss of weight and strength and pains throughout the chest. She said that she had had influenza twice in childhood. In the epidemic of 1918 she had had an attack of influenza followed by pleurisy, with effusion, and had spent about four months in bed. She stated that she had had frequent "colds" since, and had needed treatment by a rhinologist, who said that she had "sinus trouble."

On admission and for ten days before, the temperature was febrile. There was copious, occasionally blood streaked expectoration, probably largely from the nasopharynx. The physical signs of pulmonary disease were found mainly over the left lower lobe, where the percussion note was somewhat impaired; the breath sounds were weak, and many moist râles were heard. Over the right base also a few fine râles were heard. On roentgen-ray examination, the bronchial tree showed an increased shadow throughout, with thickening at each hilum. The fever subsided, the pulse was not accelerated and the sputum became less copious; improvement was slow. During the last two years, she has improved and gained in weight, yet she is still subject to "colds," with cough and expectoration. No acid-fast bacilli were found in the copious mucopurulent cocciladen sputum.

CASE 3.—E. B., a woman, aged 49, was taken ill with headache, fever, malaise, sore throat, hoarseness, cough and expectoration; later, vomited after taking food. When seen in consultation with the family physician she presented the appearance of one greatly prostrated with an acute pulmonary infection. At the age of 39, the patient had been at Saranac Lake for several months taking treatment for pulmonary tuberculosis of the right apex, which now gave signs of fibrosis. Elsewhere throughout both lungs were found the signs of bronchopneumonia, chiefly in the left lower lobe. The sputum was not blood stained, and was always scanty. Tubercle bacilli were never found, although several examinations were made. The fever lasted fifty-nine days, after which improvement was uninterrupted.

This case was one of an acute bronchopneumonia superimposed on chronic arrested pulmonary tuberculosis of ten years before without unfavorable sequelae after four months' observation.

When first seen, anxiety regarding the type of disease with which one had to do in this case arose from two points of view: First, was the process one of tuberculosis from the beginning? If the bronchopneumonia was due to other organisms, how would the disease affect

the ten postoperative, the twenty-two spontaneous, the nine postbronchiectatic, the seven postpneumonic and the eight cases which complicated either pulmonary neoplasms or tuberculosis. In all the lesions, two or more of the following organisms were identified: spirochetes, fusiform bacilli, cocci and vibrios.

This peculiar assortment of organisms is frequently found in the tonsillar crypts and around the teeth in no less than 80 per cent of the population (fig. 1). To my mind this is a point of great significance in locating the source of the infection. In six cases of pulmonary abscess, three postoperative and three spontaneous, in which I examined with the dark field apparatus both the washed pulmonary sputum and the scrapings from the teeth, not only were the same morphologic forms

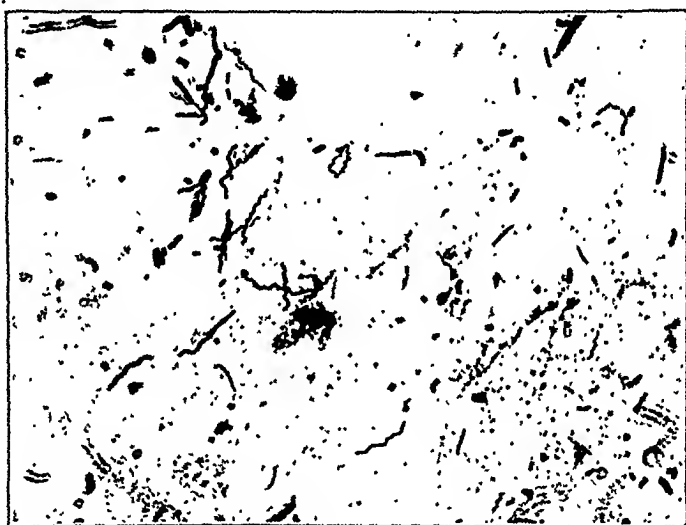


Fig. 1.—Spirochetes, fusiform bacilli and cocci from the gums of a patient suffering from moderately severe pyorrhea; fontana stain.

present, but their varying motility was identical, so that it was difficult to tell from the slide alone whether the material came from the teeth or from the lungs.

Furthermore, four cases are recorded in the literature in which gangrene or abscess of the fingers and hand followed a bite by human

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Pulmonary Gangrene, *J. A. M. A.* **81**:719 (Sept. 1) 1923. Kline, B. S., and Berger, S. S.: Spirochetal Pulmonary Gangrene Treated with Arspicnamins, *J. A. M. A.* **85**:1452 (Nov. 7) 1925. Lambert, A. V. S., and Miller, J. A.: Abscess of Lung, *Arch. Surg.* **8**:446 (Jan.) 1924. Peters: Hand Infection Apparently Due to *Bacillus Fusiformis*, *J. Infect. Dis.* **8**:455, 1911. Pilot, I.: Davis, D. J., and Shapiro, I. J.: Studies of Fusiform Bacilli and Spirochetes, *Am. Rev. Tuberc.* **8**:249 (Nov.) 1923. Pilot, I., and Davis, D. J.: Fusiform Bacilli and Spirochetes: Rôle in Pulmonary Abscess, Gangrene and Bronchiectasis, *Arch. Int. Med.* **34**:313 (Sept.) 1924.

CASE 5.—P. B., a man, aged 28, when admitted to the hospital, March 11, 1926, complained of pain and tenderness in the right side of the chest, cough, expectoration, hemoptysis, fever, night sweats, dyspnea, weakness and loss of weight. He gave evidence of serious disease. At 17 years of age he had had "pulmonary congestion," which confined him to bed for seven months. At 20 years of age, in the epidemic of 1918, he had been in bed two months with "Spanish grip." Each winter since, he had had "light grip." In June, 1925, he had suffered severe thoracic pain; later the cough had increased and expectoration had become more profuse, at times being definitely hemorrhagic. In this attack, which had lasted until August, 1925, he had noticed that the odor of the sputum was offensive. He had worked for a few weeks, but in January, 1926, the cough had become worse and the sputum once more showed blood. He had night sweating and was weak, yet he again improved, only to suffer a relapse early in March. Shortly afterward he came into the hospital.

He was weak, febrile and anemic, and had moist skin and marked clubbing of the fingers. The breath had a foul odor. At rest there was no dyspnea. The pulse rate was moderately increased. There was poor expansion and lagging of the right side on inspiration. Tactile fremitus was increased over the area of the right lung. Dulness was present from the third rib down. Signs of emphysema were present over the area of the left lung, with a few moist râles at the left base. The chief interest centered about the signs in the right side of the chest. The upper lobe appeared free. Below this, however, there were diminished breath sounds; moist and dry râles were widely heard. Moist râles were generally present. Sonorous râles were heard at varying intervals, while density or dulness was most marked in the middle of the area of the right lung. The roentgenograms taken before admission, i. e., in January and while the patient was in the hospital, indicated that there was thickening in both lower lobes, more pronounced, however, over the right, giving the suggestion of an abscess. Two months later, the roentgenogram suggested fibroid tuberculosis, with increasing and irregular shadows over the area; a right side cavity without a line of fluid level was suspected. An exploratory puncture over the dense area on the right failed to withdraw pus.

By bronchoscopy and injections of iodized oil, 40 per cent, bronchiectasis of both lower lobes was demonstrated. The sputum never showed tubercle bacilli, but *Streptococcus viridans* and nonhemolytic bacilli were found in a culture from the right bronchus. Elastic tissue was demonstrated on two occasions. The febrile condition lasted for ten days after the patient came to the hospital. Drainage was carried out. The sputum lost its foulness, lessened considerably in quantity, the density of the lung areas cleared, and the patient improved greatly. He was discharged, after seven weeks in the ward, to go to the country. To the present time, he has not reported.

#### CONCLUSIONS

The late results in these cases, as well as in practically all cases of the class under consideration, depend not only on the extent of the primary injury to the pulmonary tissue but also on the frequency of recurring and superimposed infections, and the type of infection. These results, too, we believe are dependent on circulatory disturbances, which in not a few instances are caused by toxemia and overwork acting on the heart muscle, impairing its efficiency and increasing the dyspnea, cough and expectoration, as well as the signs of chronic bronchitis.



Fig. 2.—Lungs of a guinea-pig that one month previously had received 0.5 cc. of the pyorrhea material shown in figure 1. At necropsy, three separate, discrete, well walled-off abscesses were found which contained spirochetes, fusiform bacilli, cocci and vibrios.



Fig. 3.—Lungs of a guinea-pig that had received 0.5 cc. of pyorrhea material ten days before necropsy. This abscess approaches the bronchiectatic type; in it were found spirochetes, fusiform bacilli, cocci and vibrios.

DR. D. A. STEWART, Ninette, Man.: Dr. Hamilton spoke of the many nontuberculous patients sent to sanatoriums as tuberculous. About a quarter of a century ago, a big antituberculosis campaign began, and the fact became generally recognized that tuberculosis was not a disease confined to those with gross symptoms, but was almost universal; at least, the infection was universal even if the disease was not. The pendulum swung definitely in the direction of presuming tuberculosis and putting the onus of proof on the one who would unmake rather than on the one who had made this diagnosis. Almost every pulmonary condition was suspected to be tuberculous unless positively proved to be something else. The great aim was early diagnosis. There is no doubt that there was much overdiagnosis of tuberculosis. Then came the war and the pulmonary infections that belong to the trenches, and the stream of men that came back with conditions diagnosed as tuberculosis. It will be remembered that 100,000 men were taken out of the French army and sent home because they coughed and expectorated, had blood in the sputum and fever, and that Rist organized a sifting out clinic and sent 80,000 back as not having tuberculosis. The idea began to grow then that although there was need for early diagnosis in these cases, accuracy was even more important. Then came the greater use of the roentgen ray, of the bronchoscope and of iodized oil, better bacteriology and better and newer surgical procedures for the chest, and so greater accuracy in diagnosis has begun. In the Phipps Institute a number of years ago, among patients classed as having far advanced cases of tuberculosis it was found post-mortem that 10 per cent did not have tuberculosis but had other pulmonary conditions. I think that fully 50 per cent of the patients presenting themselves at sanatoriums for diagnoses may have nontuberculous conditions, but a much smaller number are sent to sanatoriums mistakenly as tuberculous. Differential diagnoses are much better made by general practitioners than they used to be. Common colds, pneumonia and influenza have more nontuberculous than tuberculous conditions as their sequelae. The early stages of septic lung infections are among the most common conditions met. I do not agree with Dr. Hamilton that all of these patients should be referred to surgeons. Improved methods in bacteriology, of which Dr. Smith has spoken, promise better means of medical treatment. It must be remembered that even those who have definite tuberculosis may have other conditions as well, and that tuberculosis reaches its most dangerous stage when there is mixed infection. There is a much better armamentarium than ever before. The sanatorium should make diagnoses of all conditions of the chest, and perhaps give treatment for them.

DR. FREDERICK T. LORD, Boston: As to the pathology of chronic nontuberculous lung disturbances and especially to the prevalent use of the term bronchiectasis, bronchial dilatation is the most obvious incident in certain of these chronic conditions, but it should be realized that from the pathologic point of view bronchiectasis almost never exists alone. The only condition in which, from a pathologic point of view, we find it existing alone is in cases of bronchial asthma. When there are bronchial dilatations in other conditions there are important changes in the lung and usually a much more important change in the lung than dilatation of the bronchi. These cases of so-called bronchiectasis of which the roentgenologists and the bronchoscopists speak are really more appropriately called chronic bronchopulmonary infections with or without bronchial dilatation, but the bronchial dilatations may be merely incidental to more important pulmonary lesions. The usual pulmonary condition in these chronic inflammations is fibrosis of the lung tissue with or without cavity formation and bronchial dilatation. As to the differentiation of the cases of tuberculosis from



eight to ninety-six hours with extensive bilateral pneumonia. One guinea-pig and one rabbit presented widespread gangrenous and abscessed areas in both lungs. In all the lesions the fusospirochete-cocci combination of organisms was recovered.

#### COMMENT

Although a variety of organisms, including staphylococci, Friedländer bacilli or even colon bacilli, may occasionally produce lung abscess, it would seem, from experimental, pathologic and bacteriologic studies, that the common cause of this condition is the anaerobic group of organisms which is composed of (1) spirochetes of several morphologic types (*Treponema macrodentum*, *Treponema microdentum*, *Spirochaeta buccalis* and *Spirochaeta vincenti*), (2) fusiform bacilli, (3) streptococci and (4) vibrios.

#### *Organisms Found at Necropsy in Fifty-Six Cases of Lung Abscess*

Predisposing Condition	Number of Cases	Fusiform Bacilli	Cocci	Spirochetes	Vibrios
Spontaneous.....	22	22	21	15	16
Operation.....	10	10	9	9	3
Bronchiectasis.....	9	9	8	9	4
Pneumonia.....	7	7	7	7	2
Neoplasm.....	4	3	4	2	1
Tuberculosis.....	4	4	4	3	1
	56	55	53	45	27

It is probable that these organisms occasionally reach the lung by means of an infected embolus when the operative field is in an area in which they are habitually found, as in the gums and tonsils. However, the aspiration theory offers an equally good explanation for the pulmonary abscesses subsequent to operation on the upper respiratory tract, and a much more logical one for nonoperative pulmonary abscesses or those which follow a clean extrarespiratory operation.

#### CONCLUSIONS

Pulmonary abscesses have been produced in mice, guinea-pigs and rabbits by intratracheal inoculation of material scraped from the alveolar border of the teeth of patients suffering from moderately severe pyorrhea.

The same morphologic types of organisms have been recovered from these experimental abscesses as were found in both postoperative and nonoperative pulmonary abscesses in man.

Aspiration of infected material from the teeth and tonsils probably accounts for the greater number of cases of pulmonary abscess, although a small number may result from infected emboli from the upper respiratory passages.

A new addition to conservative surgical treatment was published by Sauerbruch a few weeks ago. It is for those with the subacute rather than the chronic cases of lung suppuration of the nonspecific type. He speaks of the surgical treatment of cavities near the hilum. How is it possible to get at these with greater certainty without eventually jeopardizing the life of the patient? The parenchyma of the lung must be traversed in order to reach such a cavity surgically. He has used the method of Baer, which some surgeons have used for tuberculous patients who did not respond to a complete collapse after extrapleural thoracoplasty. After apicolysis the cavity above the lung is filled with a paraffin plomb. In a number of instances—he mentions ten of these suppurating cases—Sauerbruch has resected several ribs with their periosteum, extirpated the intercostal muscles, exposing the parietal pleura. If he then saw by the motions of the lung that there were no adhesions, he did not proceed but used the paraffin, spreading it over an area the size of two hands on the parietal pleura. Then he turned back the muscles, sutured the skin completely and waited. In some instances this alone sufficed to compress the cavity sufficiently, and the latter healed. In other more aggressive cases, the compression and the changes that came about in the lung in from two to three weeks allowed the pus to perforate into the area about the plug. Then when the wound was opened and the plug removed, a number of perforations made by nature were seen. By enlarging them slightly and packing the wound with gauze the cavities near the hilum in ten patients were healed. I think that this treatment is an important addition to our conservative operative resources. But in some of these cases, if not too urgent, bronchoscopy might be successful.

I think it is agreed that in diseases of the thorax the anatomist and the physiologist, the chemist and the physicist, the internist and the surgeon, the roentgenologist and the bronchoscopist should cooperate. To continue the progress in the treatment of lung suppuration made in the last ten to fifteen years these various branches of medicine and surgery must never cease to work together.

DR. HOWARD LILIENTHAL, New York: I was much interested in Dr. Hamilton's estimate of the great number of nontuberculous patients who come to a sanatorium with a diagnosis of probable tuberculosis. It is far in excess of what I should have expected. Hemoptysis has been referred to here as occurring early in tuberculosis without previous symptoms. We know that it does occur in the progress of the disease also, and that it may be dangerous, but I wish to call attention most emphatically to the danger of hemoptysis in nontuberculous conditions, especially in the putrid forms of suppurative diseases of the lung. If I may judge by what I have seen myself, the danger of death from hemoptysis in suppurative disease of the lung is great. When a patient begins to spit blood in quantity, that is a sign that some surgical procedure should be performed because the chances of his dying as a direct result of repeated hemorrhages are great.

I do not want to be too critical, but when Dr. Lemon speaks of forced inspiration as a cause of dilatation of the bronchi from which the rigid parts had vanished, I should like to take exception. I do not think that it is the inspiration; it is the spasmodic cough that forces the air down into these bronchi with weakened walls, producing expansion. This happens in cases in which foreign bodies have been partly impacted in a bronchus and in which the cough drives some air past the obstruction which cannot get back afterward. I have not proved it experimentally, but it stands to reason that the violence of the driving of air from the sound parts of the lung into the weakened bronchi with the closed glottis, as it occurs in cough, is a much more powerful influence than

respiratory tract in the presence of an infection. One aspect of these cases which always seems to me of importance in this argument is that there is a much greater incidence of abscess of the lung in winter than in summer. This is hard to explain on the basis of embolism and easy to explain on the basis of aspiration; in the winter the respiratory tract is much more prevalently affected. I do not understand Dr. Smith to state that he regards these organisms as the established cause of these abscesses. That would be difficult to prove without the isolation of the organism in pure culture and the production of abscesses by that pure culture. I have examined the expectoration of persons with pulmonary abscess for spirochetes and almost invariably found them. They are also present in empyema, secondary to abscess and in abscess pus obtained at operations on the chest wall; so that in almost all cases of abscess the presence of these organisms may be said to be established. However, it is difficult to ascribe chief importance to them in the etiology, because they are almost invariably mixed with other organisms.

DR. A. V. S. LAMBERT, New York: Dr. Smith has accomplished something that many have been trying to do for a long time. It is interesting to compare Dr. Smith's procedure with that which others have employed. He allowed the injection to trickle in rather slowly over a fairly long period of deep anesthesia, as I understand it. This was ideal and obviously the thing to do, but it had not been done.

The organisms I was able to isolate apparently were identical with those which Dr. Smith found. I recovered the organisms from abscesses at the time of open operation through the chest wall. I subjected the animals to anesthesia and gave only one large injection into the trachea and then allowed the animal to recover from the anesthetic. I think that Dr. Smith's success lies in allowing a slow trickling in of the organism, reproducing intelligently the conditions present during operation. I failed to do this. The aspiration etiology is well established. This does not necessarily rule out all embolic cases. The ones which may have this factor as a possible etiologic factor are the cases which supervene a long time after anesthesia, usually as long as a week or ten days. It is at this time that emboli are likely to be dislodged, especially if infected. In my series of abscess cases, I saw a number that occurred from the seventh to the eleventh day after operation. In my experiments the only abscess which I was able to establish, using a pure culture of organisms obtained from lung abscesses which had been grown on a Noguchi medium, was in flea bites in the ear vein of a rabbit in which I had established a suppurative phlebitis.

DR. LEO ELOESSER, San Francisco: I should be inclined to suspect that the fact that in his experiments Dr. Smith laid bare the trachea and brought it up to the skin played a rôle in their success. It is interesting that he found first pneumonia, if I understand it correctly, and then the secondary abscess implanted on this primary pneumonia. Perhaps this might account for some of the questions Dr. Lambert has raised as to the rôle played by the spirochetes and the other invaders of the mouth. Are they merely implanted on a pneumonia, and do they cause gangrene secondarily, or are they a primary agent in causing the gangrene? Dr. Cutler's experiments are in a measure open to criticism because his method of tying off a vein, putting a small lead pellet in it and putting bacteria into this tied segment of vein is far from the conditions that cause the usual lung abscesses in human beings. It is notable, however, that by these methods he produced only a single lung abscess, and that the usual postoperative lung abscess is also single, whereas in pyemia with embolism abscesses are multiple. After the articles appeared from von Mueller's clinic

hydroxide digests the pus cells and the mucus and leaves in sharp outline any fungus that may be present in the sputum. By this method it has been possible to diagnose, at the New York State Hospital, one case of aspergillosis, two cases of oidiomycosis, five or six cases of moniliasis and one case of sporotrichosis. I cannot prove that these organisms were the cause of the nontuberculous disease, but in certain cases in which iodine was administered the organisms disappeared and the patients improved.

Cultures should be made for fungi because certain of the fungus organisms will grow when they cannot be seen in the pus, and in every case in which they are seen the diagnosis should be confirmed by a culture. Castellani recently described an anaerobic fungus that he found in certain chronic nontuberculous infections. Consequently both aerobic and anaerobic cultures should be made in every doubtful case. Many of the organisms in the lung are anaerobic, as Dr. Lambert has found, and simple aerobic cultures will give misleading results. I would suggest that smears be made of the material, and that they be stained by two or more methods. Smears should be obtained by the Gram method to show the variety of organisms, and then with some simple stain, such as methylene blue or gentian violet, to show whether fusiform bacilli are present or not. If fusiform bacilli are present, smears should be stained for spirochetes by the Fontana method.

DR. EDWARD W. ARCHIBALD, Montreal: In regard to this subject, I have had ideas along lines that have not been discussed as far as I can find. I speak of lung scars remaining from unresolved infections or partially resolved infections which have been overcome and remain in a condition of chronic infiltration, or become actual scars with localized contraction of the contiguous lung tissue. Such cases, I have read, are frequently accompanied by dyspnea and shortness of breath on slight exertion, and the roentgen ray shows one or several areas of indefinite shadow. These patients are handicapped, but not seriously. There is no question of pus and none of the condition to which Dr. Lord has referred, chronic lung infection, of which dilatation of the bronchi is only a part. Excluding bronchiectasis, abscess cases, great interference with pulmonary aeration is shown by chronic infiltrations. This indicates that the condition should be classified as one caused by lung scars, characterized by shortness of breath and disability to perform a full day's work. Is there anything surgery or medicine can do for these patients? This leads to my question, which is: In such cases, is the shortness of breath due to any compensating emphysema in other parts of the lung or to a loss of the elastic tissue such as is found in chronic emphysema with the barrel chest, so that expiration rather than inspiration is difficult? Expiration is slow. If the answer should be that this emphysema is not due to the scar itself nor to any associated bronchiectasis or infection, is there anything that can be done? I would answer my own question partly by suggesting that a slight partial compression of the emphysematous lung be performed. Is anything to be gained by slight compression which could be provided by mild unilateral or bilateral pneumothorax kept up for a considerable time, one, two or three treatments to be ultimately substituted by a small thoracoplasty?

DR. W. F. HAMILTON, Montreal: There are several points in this discussion that interest me. The first was made by Dr. Stewart. I should have put the percentage in the reverse order, that is, from 50 to 25 per cent. 50 some time ago and 25 at present, with the increasing precision of diagnosis which is admitted to be present and which may be improved. Dr. Lord's remarks about chronic bronchitis pleased me greatly. For a long time I have held the idea that diagnosis of chronic bronchitis failed when attention was directed particularly toward the

# TRANSPHRENIC INFECTION

## REPORT OF TEN CASES \*

HOWARD L. BEYE, M.D.

IOWA CITY

The diaphragm presents a striking barrier to the spread of infection from the pleural cavity. Extension through it in cases of empyema or lung abscess is remarkably infrequent. In a series of 190 cases of acute and chronic empyemas in the surgical service of the University Hospital since Jan. 1, 1915, infection has passed through the diaphragm in only a single instance (case 10), and in this patient the diaphragm was traumatized at operation.

In infections originating below and in contact with the diaphragm, however, the likelihood of the process passing upward to involve the pleural cavity or lung parenchyma is distinct. In our series of twenty-four cases of subphrenic abscess, a transphrenic infection has taken place in eight spontaneously. In another, the pleura was opened in draining the abscess, but already there was such a marked and sudden reaction in the pleura that infection of it was imminent (case 8).

This is explainable on the basis of the lymphatic drainage of the diaphragm. The latter is supplied with a rich network of lymph vessels which lie on the thoracic and abdominal surfaces of the muscle, penetrate it freely, and drain into systems of nodes which lie on the thoracic side. Probably in most cases extension of infection upward is purely lymphatic at the onset.

An uncomplicated subphrenic abscess will often present a clinical problem which is difficult to interpret and to treat. This is likely to be greatly increased when the condition is complicated by an extension of the infection above the diaphragm to pleural space or lung.

### ONSET AND CLINICAL COURSE

In this series of ten cases, three patients developed subphrenic infection as a complication of an acute attack of appendicitis. A fourth had been operated on for appendicitis two years before, and at necropsy an abscess was found extending from the diaphragm to the pelvis with a perforation into the cecum. Four patients probably had acute perforations of peptic ulcers. One patient had a perinephric infection. The tenth case was originally one of acute empyema.

Spread of the infection through the diaphragm took place insidiously in seven of the cases. In one patient a subphrenic abscess formed as a

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\* From the Department of Surgery, University of Iowa College of Medicine.

# EXPERIMENTAL ASPIRATORY ABSCESS\*

DAVID T. SMITH, M.D.

RAY BROOK, N. Y.

The apparent increase in the incidence of pulmonary abscess, especially the postoperative form, has become a serious problem for both surgeon and physician. There are two important theories regarding the cause of pulmonary abscess, the embolic and the aspiration theories. At present each has about an equal number of adherents. The evident conflict between these theories is an obstacle to the adoption of satisfactory methods of prevention. Consequently, it would seem advisable at this time to attempt to appraise their relative value.

Included among the chief supporters of the embolic theory are Fetterolf and Fox,<sup>1</sup> and Cutler<sup>2</sup> and his associates. Cutler, in a series of ingenious and well controlled experiments, produced pulmonary abscess in the dog with infected emboli. However, he was unsuccessful in his attempt to produce a similar condition in dogs by the aspiration route. He concluded from these observations that most cases of postoperative abscess are embolic in origin.

Cutler and Schlueter<sup>3</sup> compiled from the literature 1,908 cases of pulmonary abscess, of which only 30 per cent were postoperative. They made no attempt to explain the remaining 70 per cent, stating that an abscess following pneumonia or bronchiectasis was essentially different from one developing subsequent to an operation. Apparently, this view is not supported by bacteriologic or pathologic studies. I compiled fifty-six cases from the literature (accompanying table) in which the predisposing cause was known and in which bacteriologic and pathologic studies had been made.<sup>4</sup> There was no essential difference noted between

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\* From the New York State Hospital for Incipient Pulmonary Tuberculosis.

1. Fetterolf, G., and Fox, H.: The Paratonsillar Tissues in Relation to Posttonsillectomy Abscess, *Proc. Am. Laryngol. A.*, 1923, p. 252.

2. Cutler, E. C., and Schlueter, S. A.: The Experimental Production of Abscess of the Lung, *Ann. Surg.* 84:256 (Aug.) 1926. Holman; Weidlein, and Schlueter: A Method for the Experimental Production of Lung Abscess, *Proc. Soc. Exper. Biol. & Med.* 23:266, 1926. Schlueter, S. A.; Weidlein, I. F., and Cutler, E. C.: The Experimental Production of Lung Abscess, *New York State J. Med.* 26:767 (Sept. 15) 1926.

3. Cutler and Schlueter (footnote 2, first reference).

4. Buday: Histologische Untersuchungen über die Entstehungsweise der Lungengangrän, *Beitr. z. path. Anat. u. z. allg. Path.* 48:70, 1910. Fishberg, Maurice, and Kline, B. S.: Spirochetal Pulmonary Gangrene, *Arch. Int. Med.* 27:61 (Jan.) 1921. Kline, B. S.: Spirochetal Pulmonary Gangrene, *J. A. M. A.* 77:1874 (Dec. 10) 1921. Kline, B. S., and Blankenhorn, M. A.: Spirochetal

## DIAGNOSIS

A carefully taken history with special stress laid on etiology is of the greatest importance. In case 2, failure to observe this led to an inaccurate interpretation of the observations. In the chronic or latent cases with the history of an acute abdominal insult, such as perforation of a peptic ulcer or acute appendicitis, one should always suspect the presence of a subphrenic infection even though the symptoms are referable to the thorax.

The roentgen-ray study must be thorough. One may easily overlook evidence of a subphrenic abscess when concentrating attention on the intrathoracic pathologic condition. In case 2, the roentgenographic demonstration of such an abscess was neglected for weeks because of the obvious evidence of a gross pathologic condition in the lung or pleura. The roentgen ray may be misleading, however, if depended on too much. Figure 15 was the evidence for a diagnosis of subphrenic abscess, secondary to a lung infection. This proved to be an empyema with no involvement below the diaphragm. Lung mapping will help in certain cases. In case 1, it was a great aid in localizing the intrathoracic course of the intestinal-bronchial fistula. In case 2, it demonstrated a lung abscess as distinct from the subphrenic abscess beneath it.

Tenderness under the costal margin and in the flank, with rigidity of the wall, cannot be passed over too lightly in cases in which the pathologic condition is seemingly all above the diaphragm.

## TREATMENT

In this series, there were two cases in which drainage of an empyema led to an apparent cure of the subphrenic infection. In each, there was a gross defect in the diaphragm connecting the two areas. In a third, drainage of the empyema had no influence on the subphrenic infection.

In one case, drainage of a subphrenic abscess did not prevent the later development of an empyema. In one, the drainage of the subphrenic abscess has caused almost complete relief of symptoms referable to a lung abscess, with possibility of cure. In another, drainage of the subphrenic abscess was followed by death. In this case, the pleura was not grossly infected and was accidentally opened.

In two cases, a subphrenic abscess and communicating empyema were both drained. One of these patients recovered. The other died, and necropsy disclosed an extensive abscess from diaphragm to pelvis.

In one case drainage of an enormous subphrenic abscess had no great effect in clearing up the intrathoracic infection because the latter communicated with the large bowel and was not in intimate relation with the abscess at the time of operation.

teeth.<sup>5</sup> Examination of the pus from these patients revealed spirochetes, fusiform bacilli and cocci in three and fusiform bacilli and cocci without spirochetes in the fourth. These accidental infections, which are practically the equivalent of experiments on human beings, indicate that the organisms found about the teeth may, under certain conditions, become virulent for man. The foregoing observations offer strong presumptive evidence that the teeth and tonsils are the usual sources of infection in both postoperative and nonoperative pulmonary abscess.

If this view is correct, the question arises regarding the channels by which the organisms from the mouth gain access to the lungs. The following experiments were planned to determine this point.

#### EXPERIMENTAL REPRODUCTION OF PULMONARY ABSCESS

I attempted to produce pulmonary abscess in fifty mice, forty guinea-pigs, five rabbits and three dogs by intratracheal inoculation of bloody material obtained from about the teeth of patients suffering with moderately severe pyorrhea. The development of spontaneous lung abscess was not noted in any of the stock animals.

After the animals were anesthetized with ether, the trachea was dissected out and elevated to the skin surface. A small caliber needle was plunged through the tracheal wall and the infecting material injected so that it trickled down into the lungs drop by drop. The dose for mice varied from 0.05 to 0.1 cc.; for guinea-pigs, from 0.1 to 0.5 cc.; for rabbits, from 0.5 to 1 cc., and for dogs, from 3 to 5 cc. By varying the position of the animal, the material could be directed into either the right or the left lung. This technic offers no gross insult to the lungs, and simulates rather closely the circumstances under which an anesthetized patient aspirates material from the mouth.

Roughly, 30 per cent of the animals remained well, 50 per cent died of pneumonia and 20 per cent developed pulmonary abscess. The controls, ten mice and seven guinea-pigs injected with the same material rendered sterile by heating to 60 C., failed to develop pulmonary lesions. The absence of pulmonary disease in the fifteen mice and twelve guinea-pigs may probably be explained by natural resistance, by difference in dosage, by an active cough reflex which expelled the injected material from the lungs or by recovery from the infection.

Twenty-five mice and twenty guinea-pigs succumbed to pneumonia in from twenty-four to ninety-six hours following the intratracheal injections. Grossly, there was nothing characteristic about the pneumonic lesions; yet the stained smears showed spirochetes, fusiform bacilli and cocci, and anaerobic cultures yielded a growth of fusiform bacilli and streptococci. It is interesting to note that the animals that survived two weeks or longer, at necropsy showed no evidence of pneumonia; they either were normal or presented evidence of pulmonary abscess.

In the ten mice and eight guinea-pigs that developed abscesses (figs. 2 and 3), smears and cultures showed spirochetes, fusiform bacilli, anaerobic streptococci,

5. Hultgen, J. F.: Partial Gangrene of Left Index Finger, *J. A. M. A.* 55:857 (Sept. 3) 1910. Peters (footnote 4, seventh reference). Pilot, I., and Meyer, K. A.: Occurrence of Fusiform Bacilli and Spirochetes in a Gangrenous Lesion of the Finger, *Arch. Dermat. & Syph.* 12:837 (Dec.) 1925.



## DIAGNOSIS

A carefully taken history with special stress laid on etiology is of the greatest importance. In case 2, failure to observe this led to an inaccurate interpretation of the observations. In the chronic or latent cases with the history of an acute abdominal insult, such as perforation of a peptic ulcer or acute appendicitis, one should always suspect the presence of a subphrenic infection even through the symptoms are referable to the thorax.

The roentgen-ray study must be thorough. One may easily overlook evidence of a subphrenic abscess when concentrating attention on the intrathoracic pathologic condition. In case 2, the roentgenographic demonstration of such an abscess was neglected for weeks because of the obvious evidence of a gross pathologic condition in the lung or pleura. The roentgen ray may be misleading, however, if depended on too much. Figure 15 was the evidence for a diagnosis of subphrenic abscess, secondary to a lung infection. This proved to be an empyema with no involvement below the diaphragm. Lung mapping will help in certain cases. In case 1, it was a great aid in localizing the intrathoracic course of the intestinal-bronchial fistula. In case 2, it demonstrated a lung abscess as distinct from the subphrenic abscess beneath it.

Tenderness under the costal margin and in the flank, with rigidity of the wall, cannot be passed over too lightly in cases in which the pathologic condition is seemingly all above the diaphragm.

## TREATMENT

In this series, there were two cases in which drainage of an empyema led to an apparent cure of the subphrenic infection. In each, there was a gross defect in the diaphragm connecting the two areas. In a third, drainage of the empyema had no influence on the subphrenic infection.

In one case, drainage of a subphrenic abscess did not prevent the later development of an empyema. In one, the drainage of the subphrenic abscess has caused almost complete relief of symptoms referable to a lung abscess, with possibility of cure. In another, drainage of the subphrenic abscess was followed by death. In this case, the pleura was not grossly infected and was accidentally opened.

In two cases, a subphrenic abscess and communicating empyema were both drained. One of these patients recovered. The other died, and necropsy disclosed an extensive abscess from diaphragm to pelvis.

In one case drainage of an enormous subphrenic abscess had no great effect in clearing up the intrathoracic infection because the latter communicated with the large bowel and was not in intimate relation with the abscess at the time of operation.

vibrios and rarely leptothrix-like organisms. As a rule, the guinea-pigs were killed two weeks after the intratracheal inoculations, but one old male pig that seemed well nourished was allowed to live one month, and at necropsy three well walled-off abscesses were discovered, each connected with a bronchus (fig. 2).

The dark field examinations of the pus from all the experimental abscesses showed organisms morphologically identical with those recovered from pulmonary abscesses in man.

Late in the investigation, it was discovered that rabbits also were susceptible to these organisms. One of the animals died eight days after receiving an intratracheal injection of 1 cc. of material obtained from about the teeth of a patient suffering from pyorrhea. When the thorax was opened, the left lung was normal; the right showed a purulent, foul smelling empyema and several pulmonary abscesses (fig. 4). The dark field examination of the purulent fluid

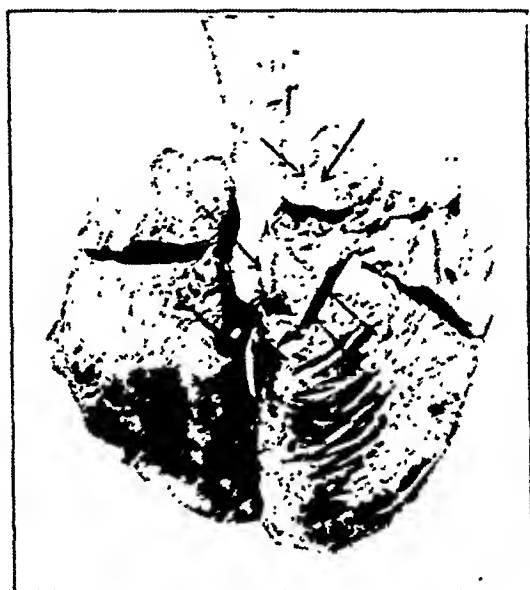


Fig. 4.—Lungs of a rabbit that died eight days after intratracheal injection of 1 cc. of pyorrhea material. At necropsy, empyema was found in the right pleural cavity, and several abscesses in the right lung, spirochetes, fusiform bacilli, anaerobic streptococci and vibrios were grown from the pulmonary lesions.

showed large numbers of spirochetes, fusiform bacilli and cocci. Cultures from the diseased lung gave an excellent mixed growth of spirochetes, fusiform bacilli and streptococci, which have now been propagated for eight generations. The results of this experiment are in accord with the observations of Kline, who in 1923 produced pleuropulmonary gangrene in a rabbit by intrabronchial injection of material from a carious tooth.

Three dogs received intratracheal inoculations of pyorrhea material which was virulent for rabbits, guinea-pigs and mice, yet at necropsy the dogs presented no pulmonary lesions.

Two rabbits and eight guinea-pigs were given intravenous inoculations of pyorrhea material. Two of the guinea-pigs remained well and were normal at necropsy. Five of the guinea-pigs and one of the rabbits died in from forty-

The hemoglobin content was 75 per cent; the red blood cells totaled 4,159,000, and the white blood cells 14,300.

Urinalysis was essentially negative.

*Operation and Course.*—An operation was performed, April 9, under ethylene anesthesia. A left muscle splitting incision below the iliac crest opened into an abscess containing more than 2 quarts (1,892 cc.) of brownish yellow pus, moderately thin, odorless and containing small clumps of fibrin. A counter drain was made in the flank. A pure culture of *Staphylococcus aureus* was grown from the pus. Drainage from the cavity persisted, with no tendency for the latter to heal. The cough and sputum were not relieved and an irregular fever persisted,



Fig. 1 (case 1).—Lung mapping with iodized oil, showing the localized accumulation in the angle between the diaphragm and the spine at the level of the tenth rib. When a barium enema was given, a narrow tortuous tract became outlined; this began in the region of the splenic flexure and passed toward the area seen in this view. When this point was reached by the barium the patient had a violet paroxysm of coughing and raised some of the barium suspension. It was not possible to get roentgenographic evidence of the tract because of the cough.

together with a leukocytosis around 15,000. Irrigation of the cavity with surgical solution of chlorinated soda (Dakin's solution) at no time induced coughing.

Lung mapping was done by Dr. L. W. Dean, and Dr. T. F. Baxter reported on the roentgen-ray examination: Fluoroscopic examination was made after the injection of the lungs bilaterally with iodized oil, 40 per cent. The base of the right lung showed a reasonably large amount of iodized oil with nothing unusual

## ABSTRACT OF DISCUSSION

DR. WILLY MEYER, New York: Dr. Smith has made an important contribution to thoracic surgery, in particular to suppurative processes of the lung. His paper is divided into two parts: the present general discussion within the medical profession with reference to the etiology of lung abscess—Is it in the majority of cases due to aspiration, or is it due to embolism?—and, second, the treatment for the foul odor of the secretions of the lung by the intravenous introduction of neocarsphenamine. I am sure that when this discussion arose as to whether the cause of lung abscess was aspiration or embolism, the greater number who have followed patients of this type clinically for some time invariably have come to the conclusion that the majority of these cases are due to aspiration. One experience in particular deserves mentioning. Suppose a purely abdominal aseptic operation has been performed, under general anesthesia; there was perfect primary union; yet a lung abscess developed. Of course, that does not always happen, because pyorrhea is present. On the contrary, I believe that often vomiting is the cause—not pronounced, but slight vomiting—when the contents of the stomach have been brought up into the pharynx, from where they were aspirated. We all know, of course, that embolism may be the cause of lung abscesses, but, I think, in the minority of cases. Now we have heard this additional contribution by Dr. Smith, who has shown that dogs are not susceptible to this kind of infection; therefore, the failures seen in the dog. I certainly am one of those who firmly believe that the majority of lung abscesses following pneumonia and influenza are due to aspiration, and aspiration not only from the bronchial tree into the finest ramifications and into the lung parenchyma, but also from the pharynx subsequent to vomiting during general anesthesia. On account of lack of time, Dr. Smith did not discuss at length the treatment for the foul odor of the sputum in bronchiectasis and in many cases of lung abscess. Last summer I first heard of Dr. Smith's experiments from one of the representatives of the health commissioner of the State of New York in our district. Having followed this aspect for many years, I wrote to Dr. Smith immediately as to what he had seen in these cases. His answer came, and later he read a paper at the annual meeting of the State Medical Society in New York. As usual, on account of lack of time, his paper could not be discussed. But here in our association we have that time. It was a most interesting observation that these partially anaerobic spirochetes and vibrios, which make these patients absolute outcasts, can be controlled even without operation by the administration of neocarsphenamine. Until this discovery was made only free incision and thorough ventilation of the bronchial tree could accomplish it. Of course, arsenic will not be effective in every case. Last fall a bronchiectatic patient received intrabronchial treatment from Dr. Kernan, and in addition Dr. Smith's treatment; the odor disappeared completely. Later, the patient left the hospital for a few weeks, and when he returned there was a slight recurrence of the foul odor. Various reasons prevented giving the treatment again. After all I have heard and what I know about Dr. Smith's experience, I consider it important to know that the spirochetes which produce this smell are amenable to treatment with arsphenamine.

DR. F. T. LORD, Boston: Regarding the relation of abscess to embolism or aspiration, it must be a question whether the presence of this sort of flora in the sputum helps much in settling that particular question. It may be that these spirochetes and bacilli are simply part of the flora of the lower parts of the

gas "through the lung." She said that about a year before when given an enema by her mother the fluid almost strangled her immediately on its being injected into the bowel.

With this additional history, the presence of a communication between the intestinal tract and the lung was suspected, and fluoroscopic examination, using a barium enema, was attempted.

*Fluoroscopic Examination.*—The barium enema passed easily to fill the entire large bowel. Shortly after the bowel was well filled, a narrow tortuous tract was seen to lead off from the region of the splenic flexure, upward and inward, to the angle formed by the diaphragm and the spine. Just as the barium reached this angle the patient had a violent spell of coughing and began to raise the



Fig. 3 (case 6).—Rapid development of an extensive empyema through a gross defect in the diaphragm.

barium suspension. She sat up abruptly, and whenever an attempt was made to have her recline, another violent paroxysm was brought on. It was impossible to get roentgenographic evidence of this tract. Roentgenograms of the chest (fig. 3) showed the iodized oil still present in the lung with a discrete accumulation between the ninth and tenth ribs close to the spine, suggestive of the sinus tract, which was demonstrated from below by barium enema.

*Second Operation and Course.*—A second operation was performed, July 20, under ethylene anesthesia. With the patient lying on the right side, a long incision was made through which all of the tenth rib and several inches of the ninth were resected. The peritoneum was opened for exploration. There were remarkably few adhesions in the left upper quadrant. The transverse and descending portions of the colon were mobile. Just distal to the splenic flexure

in Munich, who advocates the use of arsphenamine, I began using it in all abscess cases. Arsphenamine seems to clear up some of them partially, but not entirely, so that in some of these cases it has been necessary to operate later. Interested by these articles, I have made sniffs and tried to find what kind of spirochetes there were in the sputum. I have found spirochetes, just as Dr. Smith did, but I did not know what kind they were; I knew only that they were not syphilitic ones, because none of the patients bore evidence of syphilis.

DR. HOWARD LILIENTHAL, New York: The matter of bacteriology in Dr. Smith's experiments is not as important as the fact that he has shown that reproducing the conditions of operations on human beings may produce lung abscesses in animals.

DR. NATHAN W. GREEN, New York: In Dr. Smith's paper I have failed to note that he has entirely reproduced the conditions that occur in some of our operative cases in which postoperative pneumonia develops and, perhaps following it, a lung abscess. That is, I did not hear him say that he had made any abdominal incision in any of these cases in consequence of which the coughing reflex would become somewhat inhibited due to the discomfort. He spoke of one clear case in which the guinea-pig coughed out the material through his nose. This was striking, but I should like to ask him whether he has simulated the conditions in abdominal operations when in addition to the anesthesia and the aspiration of material the coughing reflex has been impaired due to the laparotomy.

DR. DAVID T. SMITH, Ray Brook, N. Y.: I will answer the last question first. I did not open the abdomen of any of the guinea-pigs because I did not want to introduce any more complicating factors than necessary. In regard to Dr. Meyer's remark about the odor: Noguchi found that pure cultures of *Treponema microdentum* gave off a foul odor. I have not been able to isolate pure cultures as yet, but mixed cultures of spirochetes, fusiform bacilli and anaerobic cocci give a foul odor when grown in pleural fluid, and this odor is identical with that in lung abscess. Dr. Lord asked whether these organisms were merely secondary to any chronic pulmonary infection. I investigated 150 cases of uncomplicated pulmonary tuberculosis, and although there was secondary infection with streptococci, pneumococci and influenza bacilli, the anaerobic group of organisms was not present. Of about 300 patients we have studied in the New York State Hospital for Incipient Tuberculosis, only three had both spirochetes and tubercle bacilli in the sputum. In a study that is being carried on now it is hoped to isolate each and every one of the organisms present around the teeth and then inject them into animals one by one until the combination necessary for the production of this disease is found. I know of Dr. Lord's work on the winter incidence of abscess. It is undoubtedly an important contribution. But it occurs to me that increased sneezing and secretion associated with these infections may tend to cause more people to aspirate anaerobic organisms in winter. In regard to Dr. Lambert's question, when I introduce this material into the lungs of an animal and an animal dies in from twenty-four to ninety-six hours, I never see abscesses; I see pneumonia. I have not seen an abscess manifest itself before eight days after the introduction of this material into the lung, and generally it is ten or twelve days before definite abscess occurs. I cannot say that it is proved, but it is indicated that abscess goes through this pneumonic stage before breaking down.

shadow was displaced somewhat to the left. Lung mapping was done by Dr. L. W. Dean, which demonstrated an accumulation of iodized oil, 40 per cent, in a large cavity at the end of the right terminal bronchus. The diagnosis was lung abscess with pleural effusion or empyema with bronchial communication.

*Operation and Course.*—An operation was performed, March 25, 1926, under ethylenic anesthesia. Resection of 3 inches (7.6 cm.) of the right ninth rib posteriorly was performed. The pleural cavity contained a large amount of clear



Fig. 4 (case 7).—Appearance twenty days after an acute perforation of a peptic ulcer. There is gas under the left side of the diaphragm and slight haziness above on the right.

serous fluid and air. The lung was partially collapsed. The base of the lower lobe was tightly fixed to the diaphragm in the region of the maximum elevation of the diaphragm. The remainder of the lobe was collapsed away from the chest wall. Palpation of the lobe was not satisfactory because of the small incision, but with the finger-tips the impression was gained that it was abnormally firm.

The incision was securely closed in layers to make an air-tight repair. The postoperative course was uneventful.

A gross defect in the diaphragm was demonstrated at operation or necropsy in four cases, excluding the patient whose diaphragm was incised at the time of operation for empyema. In three of these, the sinus was near the lateral margin of the diaphragm close to the junction between the latter and the chest wall, and in each the defect would admit the tip of the index finger. In the fourth case, the opening through the diaphragm was at the junction, on the left, between the diaphragm and its vertebral attachment. In two more cases, there was definite clinical evidence of a gross communication between the infraphrenic and the supraphrenic infection. In only three of the ten cases, therefore, the infection may have traveled entirely by way of the lymphatics without gross perforation of the diaphragm.



*Second Operation and Course.*—A second operation was performed, March 30, 1926, under nitrous oxide anesthesia. An incision in the sixth interspace anteriorly opened into an abscess lying below the diaphragm containing more than a quart (946 cc.) of foul smelling pus, gas and clumps of spongy grayish black tissue, suggesting gangrenous lung. A defect in the diaphragm could not be felt through



Fig. 6.—Roentgenogram that led to the erroneous diagnosis of a subphrenic infection secondary to a pulmonary infection. This proved to be an empyema. The dark shadow is solid lung with bronchiectasis. A bronchiectatic cavity had perforated on the diaphragmatic side of the lung, with the resultant unusual empyema. The diaphragm was displaced markedly downward but was intact.

the small incision. Below, the liver was adherent to the costal margin, thus walling off the cavity from the general cavity. An additional incision was made inferiorly to obtain dependent drainage.



*Operation and Course.*—An operation was performed, April 16, 1925, under ethylene anesthesia. The sinus openings converged to an extensive involvement of the chest wall from the ninth to the eleventh ribs, inclusive. These ribs as well as the muscles between them, were infiltrated with a thick caseous pus. In the upper portion of the wound there was a chronic empyema cavity the size of a hen's egg, well defined and containing no bronchial opening. The involved ribs were resected and the wound packed with iodoform gauze.

The patient's condition was fairly satisfactory until the fourteenth day, when the patient contracted pharyngeal diphtheria and was transferred to the isolation hospital. Here, massive doses of antidiphtheric serum were given. The wound of the chest wall became covered with a thin grayish membrane, from specimens of which cultures of a diphtheric bacillus were grown. The patient died on the eighteenth day after operation.

*Necropsy.*—This disclosed an old infectious process between the right lobe of the liver and the diaphragm, consisting of fibrous tissue permeated with small abscesses. The omentum was adherent to the liver and gallbladder, and in it were numerous small abscesses. The appendix appeared normal. This extensive area lay immediately below the involvement of the chest wall. Both lungs were adherent at their bases. The bronchi were dilated and contained pus.

This patient probably had an initial acute appendicitis with subphrenic infection. The latter extended through the diaphragm to produce an empyema and later through the chest wall to involve the ribs and soft tissues. The empyema subsequently emptied into a bronchus with partial relief, and operative drainage of the empyema and chest wall further localized the process in the pleura. The observation of an uninvolved appendix at necropsy is not incompatible with this explanation of the pathologic course, since a year had elapsed following the acute onset.

*CASE 4.—History.*—A woman, aged 24, entered the University Hospital, May 21, 1924, stating that eight weeks before she had developed malaise, aching and diarrhea. She also had had a chill and had been in bed ever since with a high temperature and great prostration. For the last two days she had had a little cough. At this time she had been told by a physician that the right lung was solid. She had lost a great deal of weight.

The social and family histories were negative. She had never had any respiratory trouble until the present illness. The appendix had been removed in 1922. There had been no history of any complication following this.

*Examination.*—The patient was slight. The general examination was negative, but there was marked fulness in the lower portion of the right side of the chest anteriorly. Expansion was poor on both sides. The percussion note was greatly impaired from the third rib downward on the right. The breath sounds were suppressed. The heart was displaced to the left. There was a well healed McBurney's scar. There was evident fulness just under the right costal margin, and this was somewhat tender. There was a marked tenderness in the angle between the twelfth rib and the spine posteriorly.

The hemoglobin content was 60 per cent. The red cells totaled 3,500,000, and the white cells 9,800. The urine was normal except for albumin 2. A roentgenogram showed a diffuse shadow on the right side of the chest from the fifth rib posteriorly to the diaphragm. The diagnosis was empyema and subdiaphragmatic abscess.



Five months before the onset of this illness, he had had a severe attack of pain in the epigastrium for a few hours, which had subsided completely. He had always complained of a good deal of belching of gas and had to be careful of his diet because of distress associated with the taking of food.

*Examination.*—The patient had considerable tenderness in the epigastrium and under the right costal margin, and both rectus muscles were held fairly rigid. There was free fluid demonstrable in the general peritoneal cavity. Tenderness in the flank just below the twelfth rib was definite but not marked, and continued forward to merge with the anterior tenderness. There was dulness over the lower two-thirds on the right side of the chest behind and in the axilla. Over this area the breath sounds were greatly diminished. The heart was displaced to the left. The roentgenogram of the chest showed a diffuse shadow on the right, merging with the diaphragm. The heart was displaced to the left. The diagnosis was perforated peptic ulcer, with subphrenic abscess and empyema.

*Operation and Course.*—The patient was operated on, Jan. 11, 1926, under procaine hydrochloride anesthesia. Aspiration in the posterior-axillary line in the seventh interspace revealed a bile stained fluid containing pus. Rib resection at this level opened into an empyema. About a gallon of fluid escaped. This was heavily bile stained at first; later it became a muddy orange red and contained heavy clumps of fibrin. It had the odor of vomitus. The cavity was drained with large tubes. A pure culture of *Bacillus coli* was grown from the pus. Drainage was profuse for the first few hours, following which it became scant. There was a decided improvement in the patient's general condition, and the tenderness and rigidity in the abdomen cleared up rapidly. When seen five weeks after the operation, there was a small sinus persisting in the wound. On physical examination, it seemed that the lung had expanded to fill the pleural cavity and the breath sounds came through clearly. Tenderness was practically gone, although it was present to a slight degree on palpation along the costal margin just to the right of the midline. The patient has since apparently completely recovered.

In this case there was acute perforation of a peptic ulcer with development of a subphrenic abscess. This perforated grossly through the diaphragm to form an empyema. Drainage of the latter established sufficient drainage of the subphrenic infection to determine a cure.

*CASE 6.—History.*—A man, aged 26, entered the University Hospital, July 29, 1926, stating that in February he had been suddenly seized with a severe abdominal pain that made him walk the floor. He had been ill for six weeks following this with high fever and marked constipation. Shortly after recovery from this, he had developed pain in the right lower quadrant of the abdomen, and had had his appendix removed. He had been fairly well for a month, when pain had recurred in the inguinal region and in the region of the appendectomy scar, and later in the back above the iliac crest. This had been aggravated by extending the leg. He had had irregular fever since the onset and had lost 50 pounds (22.7 Kg.) in weight and much strength. About three weeks before admission he had developed a cough which was not productive.

The patient had had influenza in 1919. His appetite had been irregular for years, and certain foods, such as cabbage, caused severe epigastric pain. Last summer he had had a diarrhea with stools daily for some time, but with recovery.

present. The right side of the diaphragm was normal. The greater portion of the iodized oil was in the left lung. The diaphragm movement on this side was limited, especially near its center. The iodized oil was distributed in the left base in a manner that suggested some defect in this area. It looked as though some of the iodized oil had trickled downward in the region of the left upper quadrant of the abdomen, suggesting the possibility of some communication through this side of the diaphragm. A mouthful or two of barium mixture was given to outline temporarily the cardiac end of the stomach and to assist in the localization in the left side of the diaphragm. The roentgenograms confirmed the fluoroscopic observations. The distribution of the iodized oil in the base of the left lung suggested the possibility of a defect in this area somewhat toward the median

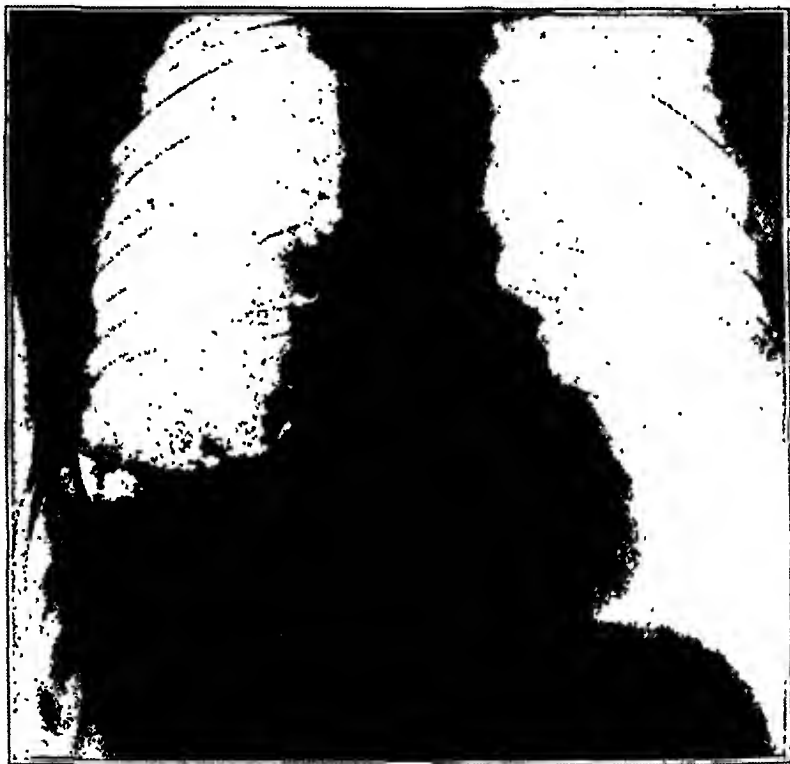


Fig. 2 (case 2).—Appearance four months after drainage of the subphrenic abscess. A mass of iodized oil remains above the diaphragm. The cough and sputum were completely relieved.

line, beneath which there was an irregular area of diminished density, probably below the diaphragm, suggesting strongly a communication between the base of the left lung and the subdiaphragmatic area.

The patient gradually improved in a general way and was sent home with the cavity draining. She returned to the hospital because of the sudden development of a high fever and chill.

She stated that one noon she had had a lunch consisting of red raspberries. The following afternoon she had suddenly had a coughing spell and had coughed up considerable sputum which contained unmistakable raspberry seeds. On further questioning, she said that during the last year on several occasions she had coughed up material which she had taken to be shreds of oatmeal and pieces of vegetable. She also stated that many times she had belched up a foul smelling

the empyema and the lumbar abscess by the fluid injected. The empyema cavity had decreased in size markedly and the temperature had fallen to normal. The patient was still under observation.

This patient probably had had an acute perforation of a peptic ulcer, or possibly an acute suppurative appendicitis. Subsequently, a subphrenic abscess had developed, a portion of which gravitated into the flank and became independent of a portion between the liver and the diaphragm. The former was drained by operation. The latter ruptured through the diaphragm to produce an empyema. Drainage of the empyema has seemingly determined a cure of the subphrenic abscess.

*CASE 7.—History.*—A man, aged 53, entered the University Hospital, Oct. 2, 1924, stating that on Sept. 16, twenty minutes after taking a dose of Bromo-Seltzer for headache, he had been seized suddenly with a terrific pain in the upper part of the abdomen. He had lain down on the floor and rolled in agony, and had vomited many times. Large doses of morphine had been given. The abdomen had become rigid and tender and, later, greatly distended. Two days later, he had begun to have diarrhea, with a stool nearly every hour. After three days of this, he had passed a large quantity of grayish, thin pea-soup-like material by bowel, following which the diarrhea had subsided. He had had slight fever. Tenderness in the upper part of the abdomen had decreased considerably, but distention had persisted. The patient had bilious spells when he ate starchy food, and he belched considerably.

*Examination.*—The pulse was 104; the temperature, 100, and respiration, 28. There was some limitation of motion of the right side of the chest. There was an area of dulness over the base on the right, where fine crepitant râles were heard. The left side was normal. The abdomen was somewhat distended and was tympanitic throughout. Tenderness was present on deep pressure under the right costal margin and in the epigastrium. Liver dulness was diminished.

An Ewald test meal was given and 60 cc. of fluid removed in forty-five minutes. Free acid was 9; total acid, 40. No blood was noted. The red cells totaled 4,000,000; the hemoglobin content 84 per cent, and leukocytes, 9,600. Urinalysis was negative.

Roentgenographic examination of the chest (fig. 10) disclosed slight cloudiness on the right side and fixation of the diaphragm. On the left there was a zone of gas between the diaphragm and the stomach. The diagnosis was perforated peptic ulcer, with subdiaphragmatic abscess.

*Operation and Course.*—An operation was performed, Oct. 21, 1924, by Dr. C. J. Rowan under ethylene anesthesia. A segment of the tenth rib was resected in the midaxillary line. Through this an abscess lying between the liver and the diaphragm was opened. About a pint (473 cc.) of thick, odorless pus escaped, but no gas. The cavity seemed to extend well to the left. Tube drainage was instituted.

The patient obtained great relief from the subjective symptoms, but continued to have a low grade febrile reaction. The abscess drained moderately a chocolate colored pus, which on one occasion was distinctly bile stained. Dulness increased over the back and in the axilla of the right side of the chest. A roentgenogram of the chest (fig. 11) on the twenty-fourth day after operation showed a slight mottled shadow above the diaphragm on the right. On the sixty-eighth day, he

was a sinus tract which passed from the posterior aspect of the bowel upward and mesially. It seemed to pass behind the peritoneum along the posterior margin of the spleen. Posteriorly, in the angle close to the spine the tract was again found. Here it passed through the diaphragm and entered adherent lung. The pleural cavity was obliterated. The tract was cut across and found to open into a lung abscess which would hold about 1 ounce (30 cc.). Into this cavity three distinct bronchi opened. A probe was passed into one of these and could be passed upward for several inches.

The peritoneum was closed without drainage. The long incision was closed in layers providing tube drainage to the lung cavity and region of the divided fistula.

The patient has had a rather sustained febrile course. The cough has been definitely less. Evidence of patency of the fecal fistula has persisted. Fecal material is occasionally found in the dressings of the posterior wound. Drainage from the lung abscess is moderate but the bronchial fistula persists. The patient is improving generally, and the temperature is gradually approaching normal. She is still in the hospital.

An acute suppurative appendicitis with diffuse peritonitis was followed by a subphrenic abscess on the left side. This ultimately drained spontaneously by two routes; into the large bowel and through the diaphragm into a bronchus, with a resulting broncho-intestinal fistula. The large subphrenic abscess present on admission to this hospital seemed to be entirely independent of the communication between the bowel and the lung. At no time did irrigation of it induce coughing.

*CASE 2.—History.*—A man, aged 44, entered the University Hospital, March 24, 1926, stating that in June, 1925, he began to lose weight and strength and have fever and sweats. He developed a slight cough. After a month he suddenly coughed up a large amount of foul sputum, and following this the cough had been more or less constantly productive of a foul tasting and smelling sputum. Serous fluid was found in the right pleural cavity and withdrawn by a needle. A diagnosis of pulmonary tuberculosis was made, and he was sent to the State Tuberculosis Sanitarium. Here, more than forty sputum examinations were negative for tubercle bacilli, and he was transferred to the University Hospital to the otolaryngologic service for lung mapping.

The past medical history was negative except for appendectomy in 1923. The patient left the hospital in three weeks apparently well.

*Examination.*—The patient was greatly emaciated, and had frequent coughing spells, producing a yellow-green, foul smelling, purulent sputum. There were signs of fluid below the level of the angle of the scapula on the right side. The heart was displaced somewhat to the left.

There was slight rigidity along the costal margin on both sides of the abdomen, especially on the right. There was slight tenderness on firm palpation under the right costal margin.

The temperature ranged around normal, with an occasional sharp rise. The leukocyte count was 8,500. The sputum was foul smelling and thick; there were no elastic fibers.

A roentgenogram of the chest (fig. 4) showed a dense shadow on the right from the midscapula to the diaphragm. The latter was obscured. The heart



Because of the patient's poor condition and the length of time that had elapsed since the symptoms of perforation, it was felt that treatment should be expectant. With supportive treatment, improvement took place until the patient was taking liquids readily by mouth. The stools were liquid black. The pain subsided almost completely and the tenderness became less marked. The epigastrium began to show a definite fullness. The temperature reached normal on the fifth day and then began to climb steadily. On the twelfth day, respirations suddenly jumped to 40, and the signs of fluid were found in the left pleural cavity for the first time. This was corroborated by roentgen-ray examination.

*Operation and Course.*—An operation was performed, May 18, 1926, under nitrous oxide. Aspiration in the eighth interspace posteriorly found a thin sero-sanguineous fluid with no fibrin flakes in it. The puncture wound was sealed. Incision was made in the seventh interspace anteriorly at the costal margin. At the upper angle, in cutting through the diaphragm a small opening was made in the pleura. This was repaired by suture. The incision was carried forward and the cartilage of the seventh rib removed. Aspiration at this point revealed foul, dirty white, thin pus. An opening was made along the needle into a large cavity containing pus and gas. The borders of it could not be reached by the finger. Shortly after the abscess was opened, it was noted that fluid was escaping from the sutured rent in the pleura, so the latter also was drained.

The patient's condition was unsatisfactory. Pneumothorax developed with respiratory embarrassment, and she died on the fifth day after operation.

*Necropsy.*—Postmortem examination disclosed a large subphrenic cavity lying between the anterior wall of the stomach, the undersurface of the liver and the diaphragm. This was secondary to a perforation through a benign ulcer situated on the anterior surface of the stomach near the lesser curvature. The left pleural cavity contained considerable thin, cloudy, blood stained fluid and air. The lung was collapsed. There was no communication between the subphrenic abscess and the pleural cavity.

An acute perforation of a gastric ulcer was followed by a subphrenic abscess. During the progress of this, the chest was examined carefully each day, and there was no evidence of fluid in the pleural cavity until the twelfth day, when there was a sudden and marked accumulation. This was not grossly infected at the time of operation, but became so subsequently owing to the opening of the pleura at operation.

*CASE 9.—History.*—A man, aged 67, entered the University Hospital, Jan. 30, 1923, stating that about ten months before he had begun to have pain in the lumbar region on the left and frequency of urination. He had lost 40 pounds (18.1 Kg.) in weight over a period of several weeks and had begun to have a frequent, hard, nonproductive cough. He had been sent to Colorado for tuberculosis but had been refused admission to a sanatorium. The prostate had then been removed. The pain in the left side of the back had persisted, and he had had a febrile course since the onset.

*Examination.*—The patient was greatly emaciated. There were signs of fluid in the left side of the chest below the angle of the scapula. The heart apparently was not displaced. There was slight tenderness below the twelfth rib on the left. The leukocyte count was 31,200. The urinalysis was: specific gravity, 1.005; albumin +; many pus cells and a few granular casts.

Further roentgenographic study in the light of the observations made at operation gave a clue to the real condition. What had been interpreted to be the upper level of an empyema cavity or indurated lung area was found to be the diaphragm (fig. 5).

A roentgenogram was made, using the portable unit, with the patient in the sitting position. This demonstrated the presence of a cavity below the diaphragm with a well defined fluid level and containing air, a pyopneumothorax subphrenica (fig. 6). Above this was a dense shadow in the lower lobe in the area that had been found so tightly adherent to the diaphragm at the time of operation.



Fig. 5 (case 7).—Appearance eight months after the development of transphrenic infection. This proved to be a well localized empyema.

The patient was now more closely questioned regarding his operation for appendicitis, and he gave the following additional data: The appendix had been gangrenous and perforated when removed, but the incision had been closed without drainage. A few days after returning home, he had had some pain along the right costal margin and had been forced to go to bed. The foot of the bed had been kept elevated for two weeks. He had been in bed for two months and had had fever during this period, but he had finally recovered, and after several months had been able to go back to work. He had been in good condition until the onset of the present trouble, an interval of more than a year.

The last diagnosis was lung abscess and subphrenic abscess.

marked tenderness, and this continued forward along the costal margin to the ensiform. The leukocyte count was 16,200. The diagnosis was subphrenic abscess.

*Second Operation and Course.*—A second operation was performed, May 18, 1919, under nitrous oxide anesthesia. An incision made in the sixth interspace anteriorly opened into a large subphrenic abscess lying between the diaphragm and the liver. It was well localized. A pure culture of pneumococcus was grown from the pus.

The patient made an uneventful recovery.

Infection from the empyema traveled through the injured diaphragm to produce a subphrenic abscess. This is the only case in this series in which infection extended from above the diaphragm to below the diaphragm.

#### SUMMARY

The diaphragm is an efficient barrier to the extension of infection from pleura to peritoneum.

Because of the lymphatic drainage, extension of infection from a subphrenic abscess to pleura or lung occurs commonly.

A gross break in the diaphragm takes place in the majority of cases with a direct connection between an infraphrenic and a supraphrenic involvement.

Drainage of either the infraphrenic or the supraphrenic infection will lead to a cure of both in some cases. Drainage of each area of involvement will be necessary in most cases.

#### ABSTRACT OF DISCUSSION

DR. EDWARD ARCHIBALD, Montreal: I looked into the matter of transphrenic infection from above downward many years ago—it must now be nearly twenty years ago. I reviewed the literature and found that out of some 500 cases of subphrenic abscess only seventeen were reported as extending from above downward; the balance were from below upward. The perforation of the diaphragm from above downward apparently is difficult.

Recovery was uneventful with almost immediate relief from fever, cough and sputum. Drainage from the cavity gradually decreased. Four months after operation, a draining cavity persisted below the diaphragm but there was only slight discharge. Irrigation with surgical solution of chlorinated soda (Dakin's solution) did not induce coughing. The patient had gained many pounds in weight and was able to do his daily work. The cough was completely relieved. Roentgen-ray examination (fig. 7) four months after operation seemed to show a cavity in the lower lobe still containing considerable iodized oil.

A subphrenic abscess developed as a late complication following the removal of a gangrenous appendix. This became latent after a period of several months' activity, and after a year of quiescence, became active and extended through the diaphragm to form a lung abscess and rupture into a bronchus.

In this case an incomplete initial history obscured the diagnosis.

**CASE 3.—History.**—A man, aged 48, entered the University Hospital, April 15, 1925, stating that in May, 1924, he had suddenly developed a sharp pain in the right lower quadrant of the abdomen, with some fever and nausea. A diagnosis of appendicitis had been made, but the operation had been deferred. After an illness of three weeks, operation had been advised, but the patient had developed what was thought to be pneumonia, and for the next four weeks he had had an afternoon temperature of 103. He had had no cough or pain in the chest. Three days after returning home, he had developed a severe paroxysm of coughing one night and had raised more than a quart (946 cc.) of foul smelling pus. Following this, he had begun to improve. Two months later, an abscess had developed in the chest wall at the base of the right axilla, which had been drained by rib resection. A month later a cellulitis had developed in this area and another rib resection had been performed. These wounds had never healed completely, and discharged a thin seropurulent exudate. A few weeks later he had developed pleurisy on the left side, which had lasted for a few days. He had lost a great deal of weight and strength and had had a febrile course since the onset.

The past medical history was essentially negative. He said that he had had no symptoms suggesting peptic ulcer. He had had double pneumonia at 19, with complete recovery.

**Examination.**—The patient was emaciated and weak. There was considerable retraction of the right side of the chest. At the base of the right axilla and posteriorly were several operative scars with two draining sinuses. On this side there was flattening of the percussion note from the eighth rib down, in the axilla and posteriorly, with absence of breath sounds. There was some impairment to percussion on the left side in the axilla.

The right rectus muscle was rigid, and tenderness was diffusely present in the right upper quadrant of the abdomen and in the loin.

The hemoglobin content was 75 per cent; the red cells totaled 3,840,000; the leukocytes, 8,200. Urinalysis was negative.

Roentgenographic study of the chest showed complete limitation of excursion of the diaphragm on the right and a dense shadow from the eighth rib to the diaphragm. The left side of the diaphragm had free excursion. The diagnosis was chronic empyema.

Within the first week or ten days the head of the embryo grows forward, and the foregut is formed from a portion of the yolk sac, which is drawn up cephalad with this forward growth; a portion of the coelom on each side accompanies this development.

The heart is developed ventrad to this portion of the foregut and becomes surrounded by the adjacent portion of the coelom as the pericardium.

The primitive trachea appears ventrad as a bud on the anterior surface of the foregut posterior or dorsad to the heart and grows downward or caudad into the axial mass of mesenchyme. Its lower end becomes surrounded by the adjacent portion of the coelom as the pericardium to form the primitive lung buds. These buds grow out laterally on both sides toward each coelomic cavity and eventually project into these cavities, pushing ahead of them a portion of the splanchnopleure, which thus covers them and which becomes the adult visceral pleura and subpleural areolar tissue. Thus it is seen that the areolar tissue of the subvisceral space is continuous with that of the primitive axial mass of mesenchyme. The adult parietal pleura is developed from the mesenchyme of the somatopleure as is also the extrapleural connective tissue, and their intimate connection with the axial mass of mesenchyme is obvious.

The well-known continuity of the connective tissue of the various fascial spaces of the neck with that of the mediastinum, as pointed out by Lerche and others, is readily accounted for by the intimate connection between the mesenchymal mass in which the primitive vessels of the neck develop and that situated mesially between the two coelomic cavities on each side.

The connection between the mediastinal and the retroperitoneal areolar tissues would be anticipated because in the embryo the original axial mass of mesenchyme is the forerunner of both the mediastinum and the mesentery.

A direct and intimate communication thus exists between the connective tissue of the mediastinum proper and that between the broad ligaments of the lung, that of the subvisceral pleural space, that about the larger branches of the bronchial tree, that of the extraparietal pleural space, that of the fascial planes of the neck and that in the retroperitoneal space, arising as they all do from the original mesenchymal mass in the embryo.

#### ANATOMY

In the adult, it is difficult to demonstrate the minutiae of this region, and on this account these relations often are not appreciated. The usual description of the mediastinum found in textbooks of anatomy may be well adapted to the purpose of enumerating the various structures con-

*Operation.*—An operation was performed, May 21, 1924, procaine hydrochloride infiltration being used. A subperiosteal resection of the ninth rib was made, opening into an empyema containing a thick, grayish yellow pus streaked with blood. The cavity was flat, and between the diaphragm and the visceral pleura and between the visceral pleura and the parietal pleura were drawn out adhesions, which tended to divide the cavity into various pockets. No gross break in that portion of the diaphragm which could be palpated, could be made out. Drainage of the cavity was made by tube. The postoperative course was satisfactory.

*Second Operation and Course.*—A second operation was performed, May 27, 1924, under procaine hydrochloride infiltration. Through the seventh intercostal space anteriorly a large abscess cavity lying between the liver and diaphragm was entered. The pus was thick. The diaphragm lay at such a high level that a gross defect in its surface could not be palpated.

After operation the patient continued to run a fairly high, irregular temperature, with a rapid pulse, and she gradually weakened. The signs and symptoms of pleurisy developed on the left side and, later, a suppurative parotitis. Death occurred on the thirty-first day following the drainage of the empyema.

*Necropsy.*—There was a large subdiaphragmatic abscess on the right side which passed behind the liver, where it extended through a sinus in the diaphragm to open into the right pleural cavity. It also extended downward behind the peritoneum, throwing the ascending colon forward to perforate into the pelvis below the cecum. Here it was in contact with the cecum, and the latter was perforated in two or three places. In the liver were found several abscesses, varying in size from a few millimeters to centimeters. The left pleura contained 2,500 cc. of a serous exudate. Mural thrombi of the inferior vena cava and right iliac vein were also present.

It is impossible to state accurately the origin of this patient's condition, but with the history of onset with diarrhea together with the symptoms of a profound infection, the chances are that an abdominal infection was the initial trouble. What the relation was between this and the operation for appendicitis may be only conjectured. The infection traveled upward behind the colon to the subphrenic region and subsequently broke through the diaphragm to produce an empyema. That there was an obliterative type of pleuritis preceding the gross infection, with the later production of purulent exudate, is strongly suggested by the type of empyema found at operation.

*CASE 5.—History.*—A man, aged 65, seen in consultation, Jan. 11, 1925, stated that about five weeks before he had been suddenly seized with acute pain in the upper part of the abdomen associated with severe shock. The upper part of the abdomen had been rigid, especially in the epigastrium, and tenderness had been diffuse. The patient had vomited. He had had no fever but a leukocytosis of 22,000. About twelve hours after the onset, jaundice had become manifest. This had persisted as a lemon yellow tinge to the sclera and skin. The condition was so desperate that operation had been withheld. He had finally improved, although tenderness and rigidity had persisted in the epigastrium and along the right costal margin. About three weeks before he had developed what had been taken to be hypostatic pneumonia. He had become cyanotic and the respirations rapid. These symptoms had gradually improved.

the pericardium, the pleurae on each side. This areolar tissue, also, is firm and unites the serous membranes firmly with each other, except along the line of reflection on the diaphragm. It is here that infection extends either forward or backward from the postpericardial portion to the prepericardial portion, or vice versa. No lymphatic vessels appear to pass between the prepericardial and postpericardial portions which might determine the course that a given focus of infection would travel.

The postpericardial and suprapericardial portions are best considered together and constitute, in most persons' minds, the mediastinum. They have important connections and extensions not usually recognized, and again most of the important structures within the thorax except the heart and lungs. They are continuous with one another and are separated only by a most artificial and arbitrary line of division which has, neither a clinical nor an anatomic basis, except that of tradition introduced for the sake of facilitating description. They are bounded on each side by the reflections of pleurae extending from the pericardium in front to the side of the bodies of the vertebrae behind. Posteriorly, they are limited by the anterior common ligament of the spine and the periosteum of the bodies of the vertebrae. Below, the space is limited by that portion of the upper surface of the diaphragm which extends from the attachment of the pericardium on the central tendon to its points of origin on the body and transverse processes of the twelfth dorsal vertebra. It should be noted that this portion of the inferior wall of the space is placed almost perpendicularly, and that it extends well down below the dome of the diaphragm and the pericardium. The openings for the passage of the esophagus, aorta, thoracic duct, azygos veins and splanchnic nerves are situated in this portion of the postpericardial space.

Above, the suprapericardial space becomes continuous with the fascial planes of the neck without any anatomic guides to distinguish the point of transition, which has been arbitrarily designated by a plane passing through the upper or inner border of the first rib and the notch of the manubrium of the sternum.

These two spaces, the suprapericardial and postpericardial, however, are roughly divided into a right and left portion by the arch of the aorta and descending aorta, the great vessels, the trachea and the esophagus.

The arch of the aorta arises from the left ventricle anteriorly behind the sternum and to the right of the median line and passes backward and to the left to become the descending thoracic aorta lying on the left side of the bodies of the vertebrae. The three large vessels, innominate, left common carotid and left subclavian arteries, arise from its upper border from before backward and from right to left; the

He also had had frequency of urination for a time, voiding hourly during the day and from three to four times at night. He had passed no blood, pus or stones.

*Examination.*—The patient was greatly emaciated. The chest was long and thin. Expansion was free and equal. The lungs were clear to percussion and auscultation. Litten's sign was present on both sides. The heart was normal in size and position. There was a well healed lower right rectus scar and some right rectus rigidity. Tenderness was present on deep palpation over the entire right rectus, laterally to the ilium and posteriorly between the iliac crest and the twelfth rib. The edge of the liver was four fingerbreadths below the xiphoid. The results of rectal examination were negative except for some hemorrhoidal masses. The temperature ranged between 99 and 101.5.

The hemoglobin content was 80 per cent. The red cells totaled 4,520,000, and the leukocytes, 15,400. The urine showed nothing pathologic. A roentgenogram of the chest (fig. 8) showed the outline of the diaphragm normal on both sides. There was no evidence of fluid in either pleural cavity. The markings of the lungs were clear.

Cystoscopy was performed by Dr. R. J. Crary. Injection of 7 cc. of sterile water into the pelvis of the right kidney caused marked distress, identical with the pain that had been present in the lumbar region. A pyelogram showed a normal pelvis. Urine drawn by ureteral catheter was negative for infection. The diagnosis was a lumbar abscess on the right side.

*Operation and Course.*—An operation was performed, Aug. 12, 1926, by Dr. F. R. Peterson, under ethylene anesthesia. An incision made between the twelfth rib and the iliac crest opened into an abscess containing about 6 ounces (178 cc.) of thick, foul smelling pus. In the bottom of this was felt the tip of a necrotic transverse process which had partially sequestered. A counter incision was made just anterior to the iliac crest. The abscess seemed well localized and did not extend upward to the level of the diaphragm. A pure culture of a nonhemolytic streptococcus was grown from the pus.

The patient had marked relief from pain. Drainage was profuse. The temperature remained irregularly elevated. On the tenth day the patient had some pain in the right side of the chest, and a coarse friction could be heard at the base. Two days later, there was dullness from the level of the scapula to the diaphragm, and roentgenographic examination of the chest showed flattening of the diaphragm and a diffuse shadow in the lower portion of the right side of the chest (fig. 9). On the fifteenth day after operation there were definite signs of fluid.

*Second Operation and Course.*—A second operation was performed, Aug. 27, 1926, under ethylene anesthesia. Pus was found by aspiration and a segment of the eighth rib was resected posteriorly. Over 1,000 cc. of a foul smelling, frank pus was evacuated from the pleural cavity. A defect was palpated in the outer, posterior quadrant of the diaphragm about an inch (2.5 cm.) from the chest wall, which readily admitted the index finger. Tube drainage was instituted. A pure culture of a hemolytic streptococcus was grown from the pus.

A profuse foul smelling pus drained from the incision for three days, with gradual subsidence. It was noted that when the patient was turned on his right side during dressing there would be a sudden gush of pus. The empyema had been thoroughly emptied at the time of operation. Irrigation of the cavity produced no cough reflex. No communication could be demonstrated between the



the vertebrae; this extends outward along the course of the ribs, the adherence being much less along the intercostal muscles. The extension of the inflammatory exudate along this path results in a massive collection of fluid which strips the pleura and accumulates outside of it; this will give rise to characteristic shadows with sharp, well defined borders, which materially lessen the normal mediastinal shadow.

The postpericardial portion of the mediastinum communicates with the retroperitoneal tissues through the several openings noted above; namely, the esophageal, most anteriorly placed immediately behind the pericardium; the aortic between the two crura and in front of the body of the twelfth dorsal vertebra, and the openings for the two splanchnic nerves represented by slits in the crus on each side where the fibers are separated to allow their passage. It should be noted that all these openings form communicating paths between the postpericardial portion of the mediastinum and the retroperitoneal tissue. We wish to emphasize the fact that this retroperitoneal space is distinct and independent of the space contained within the sheath of the psoas muscle. This sheath, it is true, extends above the diaphragm and passes through an independent opening in it on each side, but there is no pathway of communication between the postpericardial portion of the mediastinum and the areolar tissue within the psoas sheath.

#### EXPERIMENTS

We have made a number of injections into cadavers in order to demonstrate the embryologic relationships, and have employed Gerota's fluid<sup>3</sup> for this purpose. Gerota's fluid consists of a mixture of turpentine 3 parts, ether 15 parts, Prussian blue 2 parts. It has been employed extensively to demonstrate the lymphatic vessels, and has several advantages: (1) It does not stain the tissues; (2) it offers an excellent and striking contrast readily distinguished, and (3) it flows most readily. Our procedure was as follows.

The spinous processes and the laminae of the first, second and third dorsal vertebrae were removed, together with that portion of the spinal cord exposed by this procedure. We passed an 18 gage needle from behind forward through the second intervertebral disk until its tip had entered the suprapericardial portion of the mediastinum, that is, the superior mediastinum, and then injected from a syringe or allowed to flow by gravity Gerota's fluid, the amount of fluid being regulated somewhat by the size of the cadaver. As we employed only infants ranging in age from birth to 2 years, we used from 10 to 40 cc. of fluid.

The results may be summarized as follows: The fluid injected entered the mediastinum and completely filled its suprapericardial and postpericardial portions. From here it passed laterally between the layers of the broad ligaments and spread out to a variable extent in an irregular manner beneath the visceral pleura, especially over those portions of the lower lobe which lie in the vertebral gutter; it did not penetrate deeply into the pulmonary tissue except as it passed along the course of the lower bronchi. A small amount

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3. Gerota: *Anat. Anz.* 61, 1926.

coughed up 6 ounces (178 cc.) of pus resembling anchovy sauce, and following this the cough persisted in paroxysms. At this time there was a well marked area of dullness with an absence of breath sounds over the lower third of the chest posteriorly on the right, and the roentgen-ray examination showed a dense shadow in this area (fig. 12).

A diagnosis of lung abscess was made secondary to infection through the diaphragm. The cough became less, although it persisted and produced a reddish, ropy sputum.

He was discharged, and at home he gained in weight and strength. Because of the persistence of the cough and sputum and the physical signs in the chest, he reentered the hospital in December, 1925, for operation. At this time roentgenographic and fluoroscopic study (fig. 13) showed a well limited, dense shadow, lying against the posterior wall of the chest. A diagnosis of empyema was made rather than lung abscess.

*Second Operation and Course.*—A second operation was performed, Dec. 24, 1925, under ethylene anesthesia. Resection of a portion of the eighth, ninth and tenth ribs posteriorly opened into a chronic cavity lined by thick pleura and containing several ounces of bloody pus. A small bronchial opening was present at the apex of the cavity.

The patient's condition was satisfactory until the sixth day, when he developed a rapidly spreading erysipelas around the wound. This finally began to subside, but on the fourteenth day the signs of an intracranial infection became manifest, and the patient died from this on the twenty-third day after operation.

An acute perforation of a peptic ulcer was followed by a subphrenic abscess. Partial drainage took place into the bowel. Surgical drainage of the subphrenic abscess seemingly cured this condition. At the time of operation, there was clinical evidence of pleural reaction, but fluid could not be definitely observed. In spite of the satisfactory course of the subphrenic infection following drainage, the pleural involvement progressed to the sudden formation of an empyema which perforated into a bronchus.

*CASE 8.—History.*—A woman, aged 65, was admitted to the University Hospital, May 6, 1926, stating that for two months she had been losing weight and strength, and that her appetite had been poor. Ten days before admission she had suddenly felt weak and had vomited a quart (946 cc.) of thin, black material. The night before she had had a sudden attack of severe abdominal pain, which subsided only after a hypodermic injection of morphine. She had entered the hospital twenty-four hours after the onset of the pain.

The past medical history was negative except for some "gas on the stomach" for several years. She had never had pain prior to the recent attack.

*Examination.*—The patient was an extremely ill, anemic, poorly nourished elderly woman. There was a normal percussion note over both lungs, but a few crepitant râles were heard over both bases. The heart was normal in size and position. A systolic murmur was heard at the apex. The abdomen showed marked rigidity, and exquisite tenderness over its entire surface with the greatest localization slightly to the left of the epigastrium. A tympanic note was heard over the epigastrium, with a decrease of liver dullness.

The hemoglobin content was 40 per cent. The red cells totaled 2,000,000 and leukocytes, 17,000. The diagnosis was carcinoma of the stomach with perforation.

line on the bodies of the vertebrae, except that if the injection was made too rapidly or the amount of fluid was unduly large the pleura ruptured along this line. This might be interpreted as an indication that the infiltration by the fluid was slower at this point owing to greater adherence.

The fluid appeared under the skin of the back, with an invasion of the areolar tissue, having passed through the openings for the passage of the posterior branches of the intercostal nerves. Below, it invaded the retroperitoneal areolar tissue through the esophageal opening and through the slits in each crus of the diaphragm for the passage of the great splanchnic nerve.

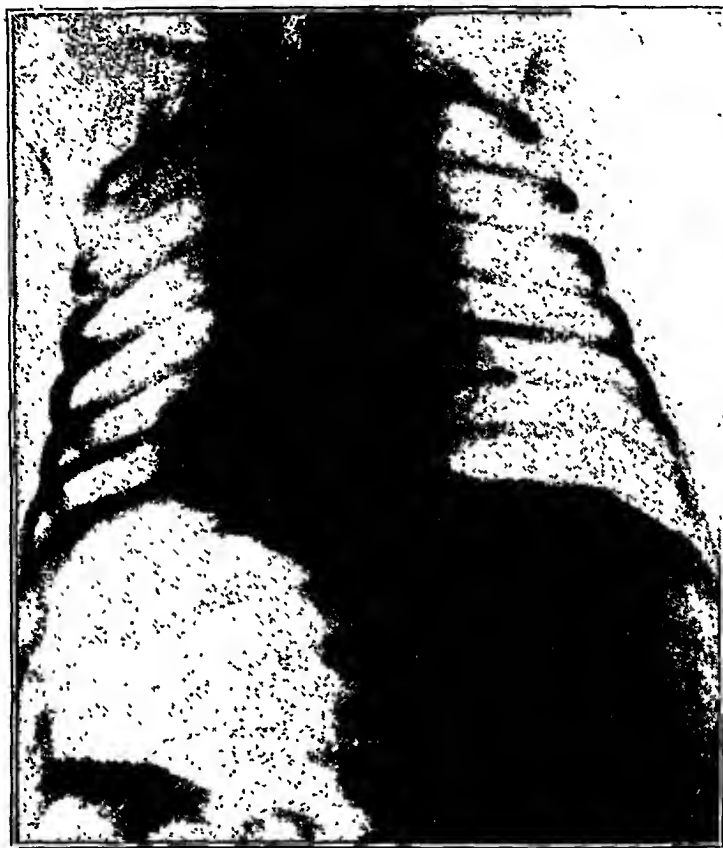


Fig. 2.—Cadaver after the injection of an opaque mixture into the mediastinum: There is a diffuse shadow from the base of the skull to the diaphragm with bilateral widening of the normal mediastinal shadow, especially above. On the right side the root shadow is due to the infiltration of the subvisceral pleural space through the broad ligament.

The extent of invasion of this retroperitoneal space varied considerably and appeared to be most pronounced when the cadaver was suspended vertically during the injection and was maintained in that position for some time afterward. The fluid injected did not pass through the aortic opening in the diaphragm. Above, the fluid invaded the neck to a wide extent. Its distribution was so general that it was impossible to distinguish whether one fascial compartment was more extensively involved than another. The fluid surrounded the vessels, both jugular veins and carotids well up toward the base of the skull; as it also appeared behind the esophagus and pharynx, it must also

A cystoscopic examination by Dr. N. G. Alcock demonstrated that the left kidney secreted satisfactorily, although dilatation of the pelvis increased the lumbar pain. Roentgen-ray examination showed a dense shadow occupying the lower portion of the left side of the chest. The heart was not displaced. The diaphragm could not be outlined. The diagnosis was chronic empyema.

**Operation and Course.**—An operation was performed, Jan. 25, 1925, under hydrochloride infiltration being used. Subperiosteal resection of the ninth rib on the left posteriorly opened into a large empyema cavity containing thick pus. In the posterior outer quadrant of the diaphragm about one-half inch (1.2 cm.) from the chest wall, was a defect which admitted the index finger. This opened into a cavity lying below the diaphragm in the region of the left kidney. A second incision of large size, was made below the twelfth rib to drain the subphrenic abscess. A pure culture of *Staphylococcus aureus* was grown from the pus.

There was considerable drainage, especially from the lumbar incision. The general improvement was gradual. The patient left the hospital with two cavities considerably smaller but still draining. He died several weeks later from cerebral hemorrhage (3).

The initial infection was probably perinephric, with later perforation of the diaphragm and development of an empyema.

**CASE 10.—History.**—A woman, aged 40, entered the University Hospital, Feb. 4, 1919, stating that about two weeks before she had been seized suddenly with a severe chill, which had been followed by pain in the right side of the chest. She had had a continuous high fever, which had reached 103, but had no sputum.

**Examination.**—Results of examination were negative except for the chest. There were signs of fluid in the lower two thirds of the right side of the chest. This was confirmed by the roentgenographic observations. The leukocyte count was 23,000. Aspiration obtained 500 cc. of greenish pus containing a diplococcus. The diagnosis was acute empyema.

**Operation and Course.**—An operation was performed, Feb. 16, 1919, under nitrous oxide anesthesia. Aspiration at the site of the former puncture obtained no pus. A segment of the rib immediately below was resected. When an opening was made through the rib bed, it was found that the diaphragm had been passed through and the peritoneal cavity opened, exposing the liver. The empyema in the diaphragm was sutured with catgut. The rib at site was resected and empyema opened. Drainage by tube was instituted.

The cavity in the pleura drained a moderate amount of pus, gradually smaller. A high post-operative febrile course was followed by a chill on the eighteenth day. The temperature reached normal, however, on the thirtieth day, and the patient was discharged as cured on the fifty-fifth day.

Shortly after she arrived home, pain developed in the right side of the chest. This was severe and sharp at times and was accompanied by a cough. It also was increased after urination. The pain gradually subsided but returned with great difficulty. She had no cough. Six weeks after discharge.

The empyema incision was healed. The chest was normal. The patient was discharged from the hospital on the fifty-fifth day.



Fig. 3 (case 1).—Bilateral widening of the mediastinal shadow from the hilum to the diaphragm, with irregular outline and extension outward.



Fig. 4 (case 1).—Marked changing of shadow coincident with recovery of patient.

# THE MEDIASTINUM

## PATHS OF EXTENSION OF INFECTION FROM FOCUS IN MEDIASTINUM\*

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The group of cases considered here has some unusual features which aroused our interest and led us to make this study of the mediastinum. Frequently the roentgenograms of patients who enter the clinic present shadows that give rise to various interpretations. In general, these roentgenograms show a widening of the normal central or mediastinal shadow. We realized that mediastinal disease was never diagnosed by roentgen-ray observation until this widening had made its appearance; in other words, until the disease had extended beyond the limits of what is usually understood as the mediastinum. The problem that has interested us most has been to determine whether the spread of mediastinal disease follows definite anatomic paths, and to endeavor to discover these paths.

### EMBRYOLOGY

A knowledge of the development of this region is important, and its embryology explains many of its peculiarities and the close relationship in the adult between what at first appear to be widely divergent structures.

In the earliest stages of the embryo, the mesoderm develops as a layer or mass of cells between the ectoderm and the entoderm, and appearing first beneath the primitive streak, spreads out as a thin plate in an ever widening circle. The portion beneath the primitive streak is spoken of as the axial mass of mesenchyme, while the peripheral area is spoken of as the paraxial mass. Soon after its appearance a cleft occurs in the paraxial portion, which separates the mesenchyme into two layers, one attached to the ectoderm, known as the somatopleure, the other associated with the entoderm, and spoken of as the splanchnopleure, while the cleft or cavity contained between these is called the coelom. In the adult, portions of this coelom become the pleural, pericardial and peritoneal cavities. The pleura is developed from the mesoderm which lines this coelom, and this mesoderm is continuous with the axial mass of mesoderm beneath the primitive streak. The axial mass will ultimately become the connective tissue of the posterior portion of the cleft mediastinum.

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for roentgen-ray examination. This continued until September 9. Physical signs and roentgen-ray examination remained unchanged. The patient became symptom-free, however, and gained 10 pounds (8.6 Kg.). In view of his improvement without any apparent change in the mass, the diagnosis was changed to probable tuberculous lymphadenitis.

Feb. 5, 1926, four and a half months later, the patient was readmitted with the complaint that during the week previous he had become increasingly dyspneic. On examination, bronchial breathing, bronchophony, dulness and many medium moist râles were noted over the right lower lobe. A succussion splash could be heard in the interscapular region. On fluoroscopic examination, a collection of fluid with air above it was seen in the upper part of mediastinum posteriorly. The impression was that of a tuberculous abscess. On February 10, the dulness and bronchial breathing were more marked over the right lower lobe and roentgen-ray examination showed extension with apparently bronchopneumonic densities in the left lower lobe. The temperature ran about 100 and the pulse was thready and weak.

On February 16, the patient coughed up about 6 ounces (178 cc.) of frothy, yellow, purulent, turbid, nonodorous fluid, and fluoroscopic examination showed that the mediastinal fluid level had descended. The cough continued, and the fluid level continued to decrease. February 20, the patient died suddenly.

The final diagnosis was tuberculous lymphadenitis of the mediastinal glands with softening and eventual rupture into a bronchus. Autopsy was not performed.

CASE 3.—M. W., a woman, aged 23, a pupil nurse, was admitted to the Presbyterian Hospital, Jan. 28, 1920, stating that she had had influenza eight days before accompanied by a pronounced coryza, but without signs of disease in the lungs. The accessory sinuses of the nose were clear.

On the tenth day of the illness, she had an attack of acute pain in the right upper quadrant of the abdomen, which was made worse on deep inspiration and which radiated into the region of the right scapula. This lasted for three days. On the twelfth day, definite signs of consolidation appeared in the right interscapular region, and the patient developed slight jaundice. The white blood cells totaled 23,600, and the polymorphonuclears, 86 per cent. A blood culture was sterile. The temperature was 104 F., the pulse rate, 112 and respiration, 34. The sputum showed a growth of *Streptococcus mucosus*. Roentgen-ray examination showed pneumonia of the right middle lobe. On the seventeenth day, the roentgen-ray report was that a hydropericardium was shown, but clinical evidence of pericarditis was not present at any time. On the fortieth day, there was an increase in precordial dulness, and the roentgenogram showed a shadow with the left border clear and the right border fuzzy. On the forty-fifth day, fluoroscopic examination showed pulsation in the left border of the heart shadow and an absence of pulsation on the right side, while the diaphragm was fixed on the right side but movable on the left. The right side of the diaphragm was high. There was a musical systolic blow over the lower end of the sternum. The sounds were always indistinct at the apex, and there was a systolic murmur over the aortic and pulmonic areas. On the fifty-second day, roentgen-ray examination showed the heart shadow of normal size with a 6 foot tube, while the diaphragm was high and firmly fixed.

The patient continued to run a febrile course of an irregular type, while the signs in the chest slowly changed. On the one hundred and thirtieth day of the illness, there was dulness over the right side of the chest posteriorly from the eighth space downward, with feeble breathing and a few fine râles.

tained within the mediastinum, but it fails to give a good mental picture which can be retained and employed to visualize in any given case the actual pathologic conditions present, while correlating physical signs and roentgen-ray observations. It is with the hope of supplying this deficiency that we have undertaken this study.

The central portion of the thorax, spoken of as the mediastinum, extends from the posterior surface of the sternum anteriorly to the anterior surface of the anterior common spinal ligament posteriorly. It is limited on each side by the reflections of the right and left pleurae; below, by that portion of the diaphragm situated between the lines of reflection of the pleurae, and above by an imaginary plane passing obliquely from behind through the upper border of the neck of the first rib, downward and forward to the upper border of the sternal notch, which roughly corresponds to the inner border of the first rib.

The pericardium, containing the heart, occupies the largest portion of this space, and it will be found convenient to have the description of the entire space focus about the pericardium, for several reasons: the diseases of the heart and pericardium form a group distinct from the surrounding structures and rarely extend beyond their original limits to involve the remainder of the space. On both physical and roentgenologic examination, the heart and pericardium serve as guides by which to judge the situation of lesions of other structures.

The remainder of the space may well be divided into prepericardial, postpericardial, suprapericardial, right pericardial and left pericardial portions.

The prepericardial portion varies considerably in extent because of the pronounced variations in the lines of reflection of the anterior edge of the right and the left pleural cavities, as pointed out by Tanja.<sup>1</sup> This space is limited in front by the muscles lining the posterior surface of the sternum and by the periosteum covering that bone. The communication on each side with the space external to the parietal pleura is particularly free, as the parietal pleura has no firm connection but is rather widely separated from the sternum by loose areolar tissue. In fact, the pleura does not become adherent until it is in contact with the costal cartilages. The pathologic process most frequently encountered in this region is disease, usually tuberculous, of the chondro-sternal or chondrocostal junctions. This does not involve the mediastinum but is situated in the extrapleural connective tissue, external to the parietal pleura. Rarely, as in case 3, a mediastinal abscess may extend forward and point beneath the sternum near the origin of the diaphragm.

The right and left pericardial portions have slight clinical significance as they are represented by a meager amount of areolar tissue between

<sup>1</sup> Tanja, T.: Ueber die Grenzen der Pleura.—*Monatsh. f. klin. Med.*, 1900, 1, 1, 11. einigen Sammelstücken, *M. J.* 17, 18-1.



totaled 16,800; polymorphonuclear 90 per cent. The urine was normal except for a very faint trace of albumin.

A tentative diagnosis of chronic pulmonary tuberculosis, with possibly encysted fluid, was made. The sputum was negative for tubercle bacilli on repeated examinations. The roentgen-ray report, Oct. 31, 1924, was, "There is an encysted effusion arising from the posterior, costophrenic portion of the right pleural cavity extending upward along the spine. There are productive changes in the bronchial walls of the left lower lobe."

The temperature ranged from 98 to 101, the pulse from 88 to 120. The signs remained essentially the same. Both by fluoroscopic examination and in



Fig. 5 (case 4).—Mediastinal abscess with enlargement of the mediastinal shadow to the right; the contour of the shadow of the arch of the aorta on the left is normal.

the roentgenograms, an encysted collection of fluid was noted to the right of the spine, but this could not be aspirated successfully. On November 6, a fluid level was first noted, and diagnoses of a mediastinal empyema which had ruptured into a bronchus and lung abscess were both considered. On November 14, postural drainage was instituted, and the temperature promptly came to normal. The sputum, which had been from 8 to 10 ounces (236 to 295 cc.) daily, gradually diminished to 2 or 3 ounces (59 or 89 cc.). Both roentgen-ray examination and physical signs showed progressive disappearance of the



fluid collection. The bronchial changes and bronchiectasis in the left lower lobe persisted.

Jan. 20, 1925, a bronchoscopic examination was made. There was a large amount of foul sputum in the larynx and trachea. This was traced to the left bronchus. No pus was found in the right bronchus. The pus from the left bronchus appeared to come from the lower lobe. The lumen of this bronchus was strictured, and the walls had undergone extensive ulceration, so that beyond the mouth of the bronchus of the upper lobe no normal mucous membrane could be seen. The narrowed ulcerated bronchus was like the mouth of a fistulous tract, through which foul pus was seen welling up. The appearance suggested an extensive bronchiectasis of the lower lobe.

During January and February, the temperature remained normal, but the sputum increased again to from 7 to 10 ounces daily (207 to 295 cc.). This was prior to the time when iodized oil 40 per cent was used for injection of the lungs. It was thought that the patient had a mediastinal abscess com-

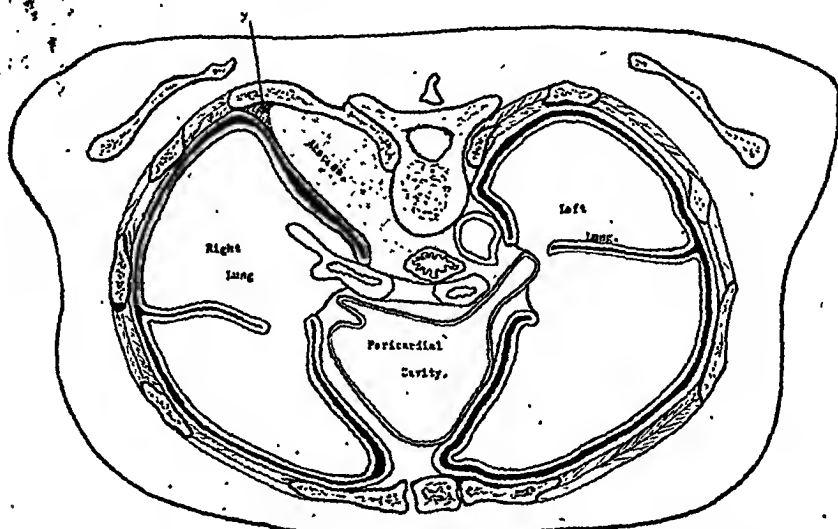


Fig. 8 (case 4.)—Cross-section of thorax representing the site of the abscess outside of the parietal pleura and communicating with the mediastinum. The thickening at the lateral border, X, causes the vertical shadow.

municating with the left bronchus; therefore, in March, a left posterior mediastinotomy was performed. No collection of pus was found in the mediastinum. The pleura was free over the left lung, but a bronchiectatic condition of the lower lobe was noted. The wound was packed until adhesions had formed, and then a cautery partial pneumonectomy was performed. Following this there was considerable improvement for about eight months but not complete alleviation of symptoms.

On account of the recurrence of fever and increase in sputum, seven months later he again came for treatment. Following an operation for further destruction of the lower lobe, he developed a pyopneumothorax and died, about one year after the acute onset of the present illness.

CASE 5.—J. C., a man, aged 27, a laborer, was admitted to the First Surgical Division, Bellevue Hospital, July 20, 1926, with a stab wound in the right side of the back. No other details were given.

Below the twelfth rib on the right was a wound 1 inch (2.5 cm.) long, bleeding profusely. The abdomen was soft but not tender. The chest was

followed the course of the larger bronchi into the pulmonary structure. None of the fluid injected passed between the pleura and the diaphragm or between the pleura and the pericardium.

Another extensive area that was invaded by the fluid injected was the retropharyngeal space. The fluid lies of the dorsal vertebral bodies and the intercostal muscles.

The distribution here was uniform and distinct, and corresponded in many particulars with the irregularities obtained by Berard and Mallet-Guy. These



Fig. 1.—Lateral view of cadaver after the injection of an opaque substance into the mediastinum: The injection mass in the retropharyngeal space which is widened in the suprapericardial portion of the mediastinum and narrowed in the posterior portion as it descends to the diaphragm.

authors demonstrated that the parietal pleura was more adherent over the ribs from the neck outward than over the anterior sternum. Our experiments showed a vertical line of increased attachment along the thoracic vertebrae. The fluid injected in our experiments did spread more readily along the intercostal spaces than over the ribs, but a definite resistance to the formation of a barrier to its free passage was observed in the retropharyngeal space.

clear. The pulse rate was 100; temperature, 100, and respiration, 24. The urine was red and cloudy and showed a trace of albumin and many red blood corpuscles. The systolic blood pressure was 104, diastolic, 75; three hours later, the systolic was 140, the diastolic, 80. In view of the injury to the kidney, the wound was explored extraperitoneally. The tissues were filled with blood clot, but only a small laceration of the kidney was found. The peritoneum appeared uninjured. The wound was drained and the kidney was not disturbed.

The patient's condition was good for seven days; then the temperature ranged from 101 to 104 F., and the pulse rate from 100 to 110. A diagnosis of subphrenic abscess was considered, but a roentgen-ray examination, August 3, showed no pathologic condition in the lungs nor any elevation of the diaphragm.



Fig. 11 (case 5).—Appearance after operation: The abscess and mediastinitis shadows have disappeared, and there are bilateral root shadows that were not present before the attack, as shown by roentgen-ray examination. The heart shadow is normal.

Cystoscopic examination, August 6, gave normal results for both kidneys.

Because of the persisting sepsis, however, the wound was reopened and a large collection of pus was found in the perinephric tissues. This wound was left wide open with the kidney lying in it superficially, and was treated with surgical solution of chlorinated soda (Dakin's solution). There was temporary improvement, but the temperature soon resumed its septic character, with wide daily swings.

August 14, dulness was noted at the base of the right side of the chest, and a friction rub was heard well posteriorly. The pulse was rapid and there was marked anemia.

have entered the retrovisceral space. This intimate relation has been emphasized by Lerche<sup>4</sup> and others.

When either the pressure or amount of fluid injected was unduly increased, the pleura was ruptured and the pleural cavity filled; otherwise it remained free. This rupture occurred either along the line of reflection, along the bodies of the vertebrae as noted above, or along the posterior part of the broad ligament near the root of the lung.

Another series of injections, following the same technique was made, employing in place of Gerota's fluid a mixture of equal parts of fresh defibrinated human blood and a 50 per cent solution of sodium iodide. This solution is opaque to the roentgen ray. It forms an injection medium which presents a pronounced contrast at the time of injection, but the color does not last and slowly diffuses into the surrounding tissues.

A series of roentgenograms was taken before and after the injection. The latter showed the shadow in the neck, extending down the mediastinum, to the diaphragm. In addition, root shadows appeared which suggest those seen in the cases of mediastinitis. The distribution of the fluid injected was identical with that obtained when Gerota's fluid was employed (figs. 1 and 2).

### CONCLUSIONS

There are definite paths by which infections may spread from a focus in the mediastinum: (1) through the broad ligaments of the lungs beneath the visceral pleura and into the substance of the lung down the larger branches of the bronchial tree; (2) posteriorly along the bodies of the vertebrae to the endothoracic fascia outside of the parietal pleura; (3) upward into the fascial planes of the neck; (4) downward into the retroperitoneal connective tissue; (5) anteriorly beneath the sternum outside of the anterior pleural reflections; (6) exudates in zone 1 will give rise to roentgen-ray shadows often spoken of as root shadows, and (7) exudates in zone 2 show large fluid collections which widen the normal mediastinal shadow.

### REPORT OF CASES

CASE 1.—A. P., a man, aged 18, an Italian, was admitted to Bellevue Hospital, service of Dr. J. A. Miller, Oct. 5, 1922, and was discharged November 14. The diagnosis was mediastinitis, with extension out the broad ligaments beneath the visceral pleura (figs. 3 and 4).

The family history was negative. The patient had had attacks of acute bronchitis one and three years before, each lasting about two weeks. Five weeks before admission, he began to have fever at 100° F. and to cough up of mucopurulent sputum each day. This condition was reported on the day of admission.

before, with pains in the lumbar region. An abscess in the back had been drained, and had healed after several months. The patient had resumed work and had remained well for four years, when he developed a slight, productive cough, with mucopurulent sputum. Shortly after this he had developed pain and swelling in the right hip. This had been incised and a large quantity of pus had been evacuated. The tissue obtained at the time of operation showed tuberculosis. This sinus had never healed, but the patient was positive that the cough had improved since the operation on the hip.

The right lung apparently was clear. There was impaired resonance in the left lung from the apex down to the seventh vertebral vertebra. Breathing was



Fig. 13 (case 7).—Appearance before operation. There is a definite widening of the upper mediastinal shadow toward the left ducto enlarged tuberculous lymph nodes.

harsh, especially on expiration, which was prolonged and bronchial in character. A few crepitant râles were heard over the left base posteriorly. In the right thigh, about 10 cm. below the crest of the ileum there was a sinus discharging a large amount of pus. This sinus appeared to run upward anterior to the neck of the femur and beneath Poupart's ligament.

The temperature was 100 F.; the pulse rate, 104, and respiration, 24. The Wassermann reaction was negative. Repeated sputum examinations were negative for tubercle bacilli.

Iodized oil 40 per cent was injected in the sinus in the thigh, and shortly afterward he coughed up the oil. Roentgen-ray examination showed a shadow





weeks before admission, the patient really dated the onset as six months back.

The patient was poorly nourished. The pupils reacted to light and accommodation. The throat was clear. Respiratory motion was limited on the left. There was dulness approaching flatness at the base below the second rib on the left, with absent fremitus and breath sounds. The right lung was clear. The heart was slightly displaced on the right. Sounds were regular; there was a blowing systolic murmur, and  $P_2$  was accentuated. The extremities were normal. The biceps and knee jerks were sluggish.

The red blood cells totaled 3,600,000; the hemoglobin content was 75 per cent; the white blood cells totaled 9,000, and the polymorphonuclears, 44 per cent. The Wassermann reaction was negative. Urinalysis showed a faint trace of albumin and a few casts. No tubercle bacilli were found in the sputum on three examinations. Ova of *Trichiuris trichiura* and *uncinaria* were found in the stools. Thoracentesis performed twice yielded no fluid. Three hookworms were found in the stools after a vermifuge. June 28, the red blood cells totaled 4,200,000; the hemoglobin content was 75 per cent; the white blood cells totaled 5,800, the polymorphonuclears, 52 per cent and the eosinophils, 24 per cent. Repeated roentgen-ray examinations of the chest showed a dense homogeneous shadow at the left base, extending up the left lateral chest wall, and peribronchovascular infiltration in the left apex.

During the first four or five weeks the patient ran a low, intermittent rise in temperature. The signs in the lungs did not change. Carbon tetrachloride and, later, nopalodium were given as a vermifuge and three hookworms were expelled; after this one expulsion no hookworm ova were found. *Trichiuris* ova continued to be present. About a week after this, the patient began to have fairly constant pain in the upper part of the abdomen. The abdomen became distended, signs of fluid were present and it had a doughy feel. The pain became worse and more constant, and the temperature began to rise to 103 or 104 F. almost daily. Two or three enlarged glands appeared in the neck. The patient lost weight steadily. The signs in the lungs did not change. Three attempts at aspiration of the chest were unsuccessful. There were no meningeal symptoms or signs. The patient was transferred to Bellevue Hospital. Heliotherapy treatments were given, cod liver oil and iodid of iron.

Shortly after admission, September 14, he was examined by Dr. Miller, whose report was: The tip of the spleen can just be felt. The liver can easily be felt 2 inches (5 cm.) below the costal margin. The signs in the chest are confined to the lower posterior quadrant on each side. The appearance on the left is characteristic of chronic pleural adhesions. On the right, although the ribs are prominent, the percussion note is dull at the angle of the scapula, and in the axilla the breath sounds are slightly diminished. There are numerous discrete glands in the cervical region, particularly on the left and in both axillae, which are more characteristic of tuberculosis than of Hodgkin's disease.

On fluoroscopic examination, the right side of the diaphragm was high, but it moved moderately; on the left, there was localized density, somewhat elliptical, laterally between the third and seventh ribs; it seemed to be pleural and partly calcified. There was a shadow slightly less dense than the heart shadow to the left of the midline of the mediastinum, extending from the heart shadow to the clavicle. It seemed to be a distinct mediastinal shadow which did not bulge and did not pulsate except by transmitted pulsation. The appearance was that of mediastinal glands which may have suppurated.

The roentgen-ray report of September 8 was that there was a large mass in the median portion of the left upper lobe and hilum. The posterior medias-



have been treated surgically. These cases were formerly considered unusual — so rare that some years ago when I was studying the subject I could find few instances of mediastinotomy for suppuration. These cases resemble mediastinitis in the roentgenogram. Surgical diagnosis and treatment by these methods will doubtless save many lives.

DR. NATHAN W. GREEN, New York: Dr. Lerche at a previous meeting also presented anatomic pictures of mediastinal infections. Each year the general surgeon should be informed concerning this condition and given better methods of treating it.

DR. WILLIAM LERCHE, St. Paul: I have had a few more cases of mediastinal suppuration, since my report of three years ago. The cases I shall report at this meeting may show the way mediastinal suppuration begins, that is, in the mediastinal lymph nodes, particularly the tracheobronchial nodes.



The right tracheobronchial space (fig. 2), containing from five to seven lymph nodes, is bounded below by the right pulmonary artery and the right main bronchus, to the left by the trachea and the ascending aorta, anteriorly by the superior vena cava, and to the right by the mediastinal pleura above and the azygos vein below. The space is narrower above on account of the course of the right vagus nerve posteriorly and the innominate artery to the left. In figure 3 is shown the arrangement of the lymph nodes in this space.

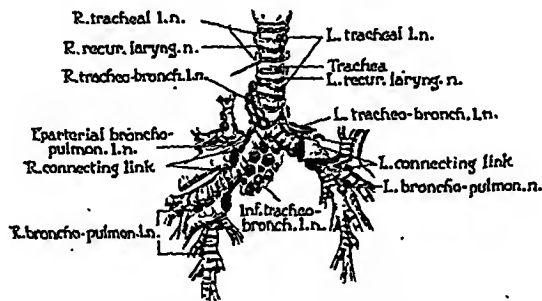


Fig. 1.—The tracheobronchial lymph nodes (Sukiennikow).

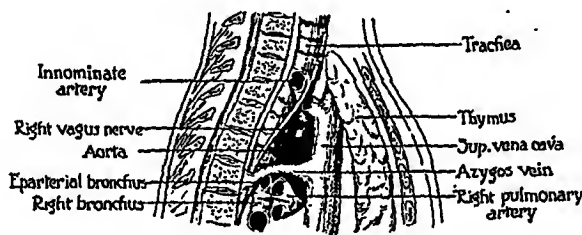


Fig. 2.—The right tracheobronchial space (Sukiennikow).

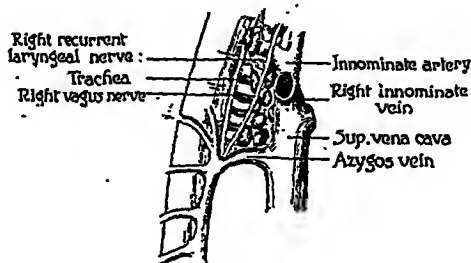


Fig. 3.—The right tracheobronchial group of lymph nodes (Sukiennikow).

#### REPORT OF CASES

CASE 1.—A farmer, aged 46, weighing 180 pounds (81 Kg.), had had pleurisy at the age of 31, with good recovery, and a severe attack of influenza at the age of 39. Since the attack of influenza he had been troubled with a dry hacking cough and frequent "colds." About three months prior to consultation, he had noticed pain in the upper part of the chest behind the sternum and to the right. Two months later, the pain had become severe and had radiated throughout the upper part of the right side of the chest, increasing in severity on coughing, deep



was no evidence of compression of the esophagus as seen through the esophagoscope. The diagnosis was mediastinal abscess due to suppuration of the right tracheobronchial group of lymph nodes.

Anterior mediastinotomy for drainage was advised, but the patient insisted on postponing the operation for a few days. Twenty-four hours later, he had a violent attack of coughing and expectorated about a pint of pus. Bronchoscopic examination, made three days after the discharge of the abscess, disclosed a dark recess on the anterior wall of the trachea to the right near the bifurcation, which evidently was the avenue of exit for the pus. The leukocyte count at this time was 9,800. All symptoms had disappeared, and the patient felt well. A culture from the pus showed mainly pneumococcus. Tests on guinea-pigs that were inoculated were negative for tuberculosis. It was by the aid of the bronchoscope that the diagnosis could be clinched in this case by observing the inflamed condition of the mucosa at the right tracheobronchial angle, corresponding to the anterolaterally situated group of lymph nodes in the right tracheobronchial space. The fact that all symptoms were less severe at the time of consultation than they were three weeks earlier was probably due to the escape of the pus from the narrow confines of the tracheobronchial space, which

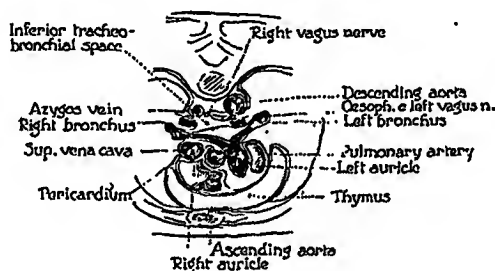


Fig. 5.—The inferior tracheobronchial space seen from above: cross section of fourth and fifth dorsal vertebrae (Sukiennikow).

relieved the pressure on the organs forming its walls. It will be noticed that although the patient had pain on swallowing, he experienced only occasional dysphagia, due probably to pressure on the vagus, which forms a part of the posterior boundary in the right space. He had only occasional dyspnea, because, although there was pressure on the tracheobronchial angle and there was some edema of the mucosa, the bronchial tube was not compressed, as seen by bronchoscopic examination. There was pressure on the vessels. The abscess in this case pointed forward, and I proposed to drain it through an anterior mediastinotomy. On the other hand, an abscess in this space might extend upward between the right carotid artery, the trachea and the spinal column and be drained through the neck or through a posterior mediastinotomy.

The inferior tracheobronchial space (figs. 1 and 5) contains from nine to twelve lymph nodes and is bounded anteriorly by the pericardium; laterally and above, by the two main bronchi and the bifurcation; posteriorly to the left, by the esophagus, and posteriorly to the right, by the dorsal vertebrae and the vessels and nerves placed on them; below, the space extends to the level where the pulmonary veins enter the left auricle.

August 17, roentgen-ray examination showed a vertical collection of fluid to the right of the spine from the eighth to the third rib. The heart shadow was enlarged and apparently rotated. A diagnosis of mediastinal abscess was made, and the abscess drained by a right posterior mediastinotomy, with resection of the heads of the sixth and seventh ribs. Following this the patient gradually improved. Roentgen-ray examination showed progressive clearing of the mediastinum. Small root shadows persisted. The patient seemed better and the wounds appeared healthier; after fifteen days, the temperature ranged from normal to 100, with occasional flares. On the twenty-sixth day postoperative his temperature suddenly rose to 104 F. and his pulse



Fig. 12 (case 6).—Mass of iodized oil, 40 per cent, injected into sinus of the thigh, crossing the median line on the body of the twelfth thoracic vertebra; i. e., within the mediastinum.

rate to 140. The abdomen was rigid and distended, and a diagnosis of diffuse peritonitis was made. He died seven days later, thirty-four days after the mediastinotomy, or on the seventy-first day of the illness.

Autopsy showed a suppurative nephritis of the right kidney, an acute diffuse suppurative peritonitis, a drained suppurative mediastinitis and an edema of the right lower lobe about the hilum, but no pneumonia.

CASE 6.—P. G., a man, aged 47, an Italian tailor, did not recall having received any severe injury. The present illness had begun about five years



of barium appeared as a thin broad band. The right part of the posterior boundary of this space (the spinal column) was on a plane posteriorly with the left part of the posterior boundary (the esophagus), permitting the latter to be compressed, laterally from right to left.

In cases 1 and 2, the dry hacking cough has ceased since the discharge of the abscesses.

I feel certain that if bronchoscopic and esophagosopic examination had been carried out in this case, there would have been no difficulty in



Fig. 7 (case 2).—Oblique view of abscess, *a, a, a, a*; of esophagus, *b, b*.

establishing a definite diagnosis. A posterior mediastinotomy would be the method of choice in draining the abscess in this case.<sup>5</sup>

The left tracheobronchial space (fig. 8) contains from three to six lymph nodes. Its boundaries are, posteriorly, the esophagus and the descending aorta; to the left, the ductus arteriosus; to the right,

5. This case occurred in the practice of Dr. E. V. Goltz of St. Paul, who allowed me to study the history and the roentgenograms.

in the retroperitoneal tissue about both kidneys and a shadow in the left bronchial tree. The connection between these two was not demonstrated until the injection was carried out with the patient lying on his ventral surface. The figure shows the result of the roentgenographic series.

The patient refused operation and subsequently died of amyloid degeneration of the liver and kidneys, with ascites.

CASE 7.—Q. W., a Chinaman, aged 18, was admitted to Bellevue Hospital, service of Dr. J. A. Miller, Aug. 30, 1926, and died, September 29. The diag-



Fig. 14 (case 7).—Appearance after operation: The abscess was drained through a left posterior mediastinotomy, with resection of the fifth and sixth ribs; the shadow has disappeared.

nosis was tuberculosis and abscess of the mediastinum. He had been transferred from the Presbyterian Hospital, where the diagnosis had been sero-fibrinous pleurisy. He had complained of pain in the right side of the lower part of the chest of from three to four weeks' duration. The past history had been essentially negative. The patient had had no other respiratory symptoms, and no cardiac or gastro-intestinal complaints. Six months before admission, he had had a cold, and although the pain in the chest had begun only three or four

of barium at  
boundary of the  
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compressed.

In the  
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ld not be passed. At times the baby became cyanotic  
tube. On being fed with a spoon, the baby cried at  
erature was 100. The result of a Pirquet test was  
of the chest had been taken, and a diagnosis of  
lung with fluid in the pleural cavity had been made.  
tillation four days before death. Another roent-  
ken (fig. 9). My diagnosis was atelectasis of the  
are on the left main bronchus by enlarged lymph  
nodes in the left  
space or to a foreign body in the left bronchus  
a growth at the hilum. An endoscopic examination was  
not made, as the p's condition was poor.

At necropsy atelectasis of the left lung was seen. The heart was large; there was left-side hypertrophy, with slight hypertrophy of the right side of the heart. The left auricle was considerably dilated, with marked thinning of the wall of the apex. The valves were normal. The ductus arteriosus and foramen ovale were closed. There was an anomaly of the coronary system, the left coronary artery rising from the pulmonary artery instead of the aorta. The anomalous coronary had the distribution of the normal left coronary artery. The right and the inferior groups of the tracheobronchial lymph nodes were

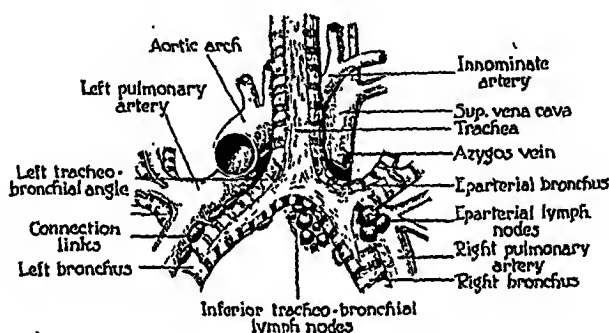


Fig. 10.—Posterior view of trachea; eparterial lymph nodes.

not enlarged, while the left group formed a large mass the size of a lima bean, and the chain of lymph nodes along the left side of the trachea showed considerable enlargement. The large mass of lymph nodes noted undoubtedly exerted pressure on the left main bronchus, being between the latter and the aortic arch above, while the enlarged heart, according to the pathologist's report, pressed on the left bronchus from below. The left recurrent nerve, which is usually in close contact with the left tracheobronchial lymph nodes (fig. 18), was exposed to pressure, hence the pronounced hoarseness. The esophagus forms the right part of the posterior boundary and is also exposed to pressure. Microscopic examination revealed hyperplasia of the left tracheobronchial lymph nodes. Unfortunately, a bacteriologic examination of the affected lymph nodes was not made. On cadavers I have tried the approach to the left tracheobronchial space, both through an anterior as well as a posterior mediastinotomy, and it seems as if the anterior route would be the easier.

In order to demonstrate the effect of pressure on a bronchus by enlarged lymph nodes, I report case 4. The ventral eparterial bronchopulmonary group contains from three to four lymph nodes situated at the angle of the eparterial bronchus (fig. 10).

tinum was clear. There was transmitted pulsation of this mass. The diagnosis was enlarged glands (?) or new growth (?). There was an effusion in the left pleural cavity, the upper level of which was at the seventh rib posteriorly.

On September 15, it was thought that a shifting fluid level could be seen under the fluoroscope. A diagnosis of tuberculous abscess of the mediastinum due to suppurating glands was made, and the patient was referred for operation.

September 21, a left posterior mediastinotomy with resection of the sixth and seventh ribs was performed. The pleura was separated from the sides of the vertebral bodies and the aorta exposed, together with the mediastinal pleura. Induration of the tissues and enlarged glands were found. The wound was closed without drainage.

On September 29, the wound broke open and from 4 to 5 ounces (118. to 148 cc.) of foul, brownish yellow pus was discharged. A finger was inserted, but no opening could be found leading across the aorta. Roentgenograms taken at this time showed complete clearing of the mediastinal abscess.

The patient died the same day.

### ABSTRACT OF DISCUSSION

DR. HUGH AUCHINCLOSS, New York: I have had confirmation of the truth of many of the statements, made not only in malignant tumors of the which spread to the mediastinum and thence along the different parts Dr. Lambert has spoken of, but also in a case of inflammation which I cite briefly. A young baseball player slid and scratched the left thigh, it dressed on Wednesday. On Thursday he neglected it. On Friday it dressed. On Saturday he did not return to have it dressed. On Sunday it developed; he became ill and went to the infirmary. On Monday he was brought to New York and entered the Presbyterian Hospital, with hemolytic streptococci in the blood. He was desperately ill, and on Wednesday he died. Besides the usual symptoms associated with hopeless sepsis, he had rigidity of the abdomen and signs of fluid and consolidation in both sides of the chest, and a disturbingly large area of dulness in the front of the chest. The two little wounds were not important and dried up. At autopsy there was fibrin in the peritoneal cavity and fluid throughout. No visceral source for this infection could be found. The lymph glands in both iliac regions were large and soft. No abscesses were found in these glands, but when the aorta and the vena cava were raised, a chain of lymph glands containing abscesses, some almost 1 cm. in diameter, were found. They contained pus and hemolytic streptococcus. This chain ran up the posterior abdominal wall into the chest along the route of the thoracic duct. On either side there was a hemolytic streptococcus pneumonia with fluid in the pleural cavities and in the pericardiac sac. The lymph glands along the posterior mediastinum still showed little abscesses. The most striking thing, however, was that just below the junction of the thoracic duct and the vein was a lymph gland that was discharging pus from an abscess directly into the duct. This pus in the duct was, of course draining directly into the vein. Thus, infection of the retroperitoneal and mediastinal spaces was started by a scratch in the thigh, and this was followed by peritoneal and serous cavity involvement. Drs. Lambert and Berry have shown this condition diagrammatically; this case would seem to be clinical confirmation of the truth and importance of their observations.

DR. HOWARD LILIENTHAL, New York: I am grateful to Dr. Lambert for having shown these excellent anatomic pictures, but still more because he has demonstrated such a number of cases of suppurative mediastinitis that

CASE 4.—A child, aged 10 months, developed cough with a peculiar stridor so suddenly that it was thought that a foreign body had entered a bronchus. Roentgenograms (fig. 11) showed enlarged bronchopulmonary and tracheobronchial nodes, atelectasis of the upper right lobe and overdistention of the lower lobes. Through the bronchoscope, I saw the lower wall of the eparterial bronchus pushed against its upper wall so as to obliterate the passage (fig. 12). A mass of tuberculous lymph nodes of the eparterial group was the cause of complete obstruction of the upper lobe bronchus and partial obstruction of the lower lobe bronchus.

Bartels, quoting W. J. Se, states that the posterior mediastinal lymph nodes, from eight to twelve in number, lie on the thoracic aorta and the esophagus.

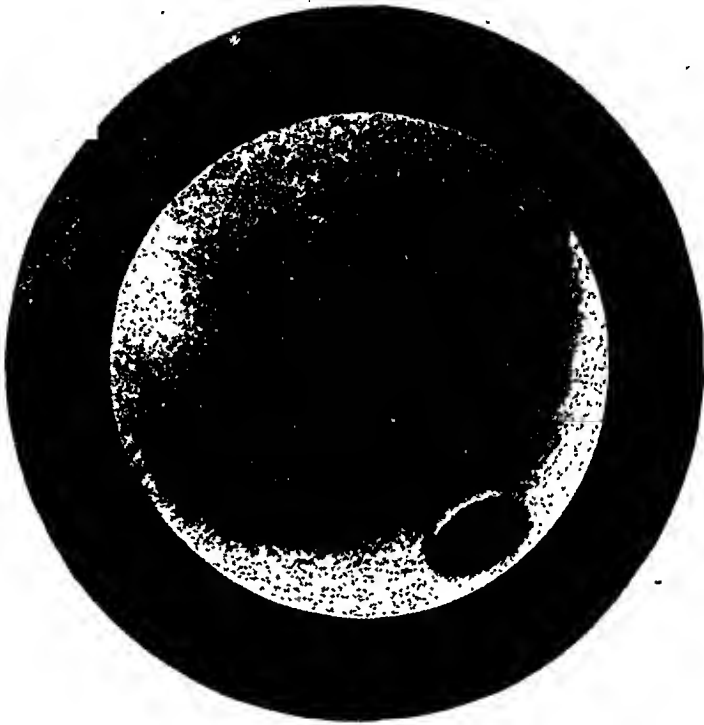


Fig. 13 (case 5).—Fistulous opening in esophagus.

According to Sakata,<sup>7</sup> the posterior mediastinal lymph nodes are scattered around the thoracic aorta, from the level of the tracheal bifurcation to the hiatus oesophageus.

CASE 5.—A woman, aged 26, complained of cough following an attack of influenza with pneumonia three years previously. The cough had increased, and for several months before the consultation she had noticed purulent expectoration and also that a part of the liquids that she took were coughed up. Occasionally, the expectoration had been blood streaked.

Esophagoscopic examination revealed an opening in the wall of the esophagus, posteriorly to the right, communicating with a cavity in the mediastinum, which was filled with bits of an apple that she had eaten the day before and which I

6. Bartels, P.: *Das Lymphgefässsystem*, Jena, 1909.

7. Sakata, K.: *Ueber die Lymphgefäße des Oesophagus und über seine regionären Lymphdrüsen mit Berücksichtigung der Verbreitung des Carcinoms*, Mitt. a. d. Grenzgeb. d. med. u. chir. 11:634, 1903.

# INFECTED MEDIASTINAL LYMPH NODES. AS A SOURCE OF MEDIASTITIS

WILLIAM LERCHE, M.D.

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The mediastinal lymph nodes often become infected in diseases of the respiratory tract, and preeminently so the tracheobronchial groups, which, according to Most,<sup>1</sup> receive the lymphatics from the lungs, bronchi, the lower part of the trachea and its bifurcation. In whatever way the micro-organism enters the lung, whether by penetrating the bronchial mucosa near the hilum and spreading in the interstitial tissue and lymphatic system to the lung, as shown in the experiments on monkeys with streptococcus and pneumococcus by Blake and Cecil,<sup>2</sup> or hematogenously as demonstrated by Krause<sup>3</sup> in experiments with tubercle bacillus in guinea-pigs, the micro-organism ordinarily is carried off from the lungs and bronchi by the lymphatics to the tracheobronchial lymph nodes. The importance of the tracheobronchial nodes as a germ-harboring depot cannot be overestimated. It has repeatedly been shown that virulent micro-organisms may be present in these lymph nodes without any other demonstrable focus in the body.

Although an abscess of the tracheobronchial nodes may discharge into a bronchus and healing take place, there are a number of necropsies reported in the literature in which it was found that abscesses from suppurating lymph nodes had ruptured into one of the large blood vessels or into the heart and other organs in the mediastinum. Therefore, surgical measures for the proper drainage should be instituted as soon as diagnosis is made.

In order to be able to make an accurate diagnosis and to carry out the proper surgical treatment, a definite knowledge of the topography of the various groups of lymph nodes and their relation to the surrounding organs is essential, and each group will therefore be reviewed briefly with the case reports.

The tracheobronchial lymph nodes consist of three main groups (fig. 1) situated in the right, in the left and in the inferior tracheobronchial spaces as described by Sukiennikow.<sup>4</sup>

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1. Most, A.: Ueber die Topographie des Lymphgeßaszapparates im kindlichen organismus und ihre klinische Bedeutung, Arch. f. Kinderh. 48:, 1908.

2. Blake, F. G., and Cecil, R. L.: Pathology and Pathogenesis of Pneumococcus Lobar Pneumonia in Monkeys, Exper. Med. 31:445-474 (April) 1920; Experimental Streptococcus Hemolyticus Pneumonia in Monkeys, ibid. 32:401-426 (Oct.) 1920.

3. Krause. A. K.: Tuberculosis in the Guinea-Pig After Subcutaneous Infection, with Particular Reference to Tracheobronchial Lymph Nodes, Am. Rev. Tuberc. 4:135 (May) 1920.

4. Sukiennikow, W.: Topographische Anatomie der bronchealen und trachealen Lymph drüsen. Berl. klin. Wehnschr., 1903, p. 316.

removed. The opening was situated in the upper part of the lower third, it was almost circular in outline (fig. 13) and the margin was well covered with epithelium, indicating that it had been present some time. On fluoroscopic examination with a barium mixture, the latter was seen to pass through the fistulous opening in the esophagus and, having filled the cavity in the posterior mediastinum, enter the right lung, and ascending through the bronchi to be finally coughed up (fig. 14).

In this case, lymph nodes in the posterior mediastinum, which drain the esophagus as well as the mediastinal pleura, had probably become infected from



Fig. 16 (case 6).—Abscess cavity in mediastinum, *a*, and fistula to esophagus, *b*.

the right pleura during the attack of influenza, the abscess ulcerating into both the esophagus and the right lung. In figure 15 is shown the method by which the cavity was treated by the application of silver nitrate solution or tincture of iodine twice a week through the esophagoscope. After a few weeks of treatments, the cough ceased, and the patient did not expectorate any of the ingested liquids. The cavity apparently was getting smaller, and her general health improved. However, the patient did not return for further treatment, so I did not have the opportunity to see the ultimate result of this treatment. My plan was later to cauterize the mucosa of the opening with actual cautery through the esophagoscope.

breathing or walking. Pain also had been felt between the shoulders, but had not been so severe. The dry cough had become worse, and he had had frequent frontal headaches accompanied by nausea and occasional vomiting. He had had pain on swallowing and, occasionally, dysphagia and dyspnea. He had had a feeling of pressure in the chest, a choking sensation and palpitation of the heart on slight exertion. He had had to sleep with the head and shoulders high. All these symptoms were less pronounced at the time of consultation than they had been three weeks before.

Inspection revealed swelling in the region of the right second costal cartilage and in the first and upper part of the second interspace. On palpation this area



Fig. 4 (case 1).—Mediastinal abscess, *a, a*.

was found sensitive. Auscultation was negative, except for roughness of breath sounds over the larger bronchi on the right side. Percussion revealed dullness over the sternum and the area in the first and second right interspace. The leukocyte count was 5,600; the temperature, 97.4; the pulse, 80, and respiration, 30. Fluoroscopic examination showed an abnormal shadow in the upper part of the chest behind the manubrium, in the upper part of the sternum and through posteriorly beyond the arch of the aorta to the spinal column, as seen in figure 4. On bronchoscopic examination, the first part of the right main bronchus and the adjoining part of the trachea were red, inflamed and somewhat edematous. There



side of the diaphragm was seen to be on a considerably higher level than the right (fig. 17); on expiration, it reached the upper border of the fourth rib. The condition improved, and five months later the left side of the diaphragm was on a lower level, but was not quite normal. In March, 1922, she had pleurisy on the left side, and the left side of the diaphragm in full expiration extended to the middle of the third rib.

The patient later developed tuberculosis of the apex on the left, and there was thickening of the pleura on the left. Her present state of health is apparently good. A recent fluoroscopic examination, more than five years after the insufficiency of the diaphragm was first noticed, showed the left side of the diaphragm 2.5 cm. below the right in deep inspiration, and less than 1 cm. above the right side of the diaphragm in full expiration.

The left phrenic nerve is in close proximity to the preaortic group of lymph nodes, and I believe that infection of these nodes with a periaadenitis involving the phrenic nerve was the cause of the insufficiency of the left side of the diaphragm in this case. Figure 18 shows a sketch from a cadaver in which the phrenic nerve was firmly adherent to the preaortic lymph nodes. Such cases of nonsuppurative mediastinitis are

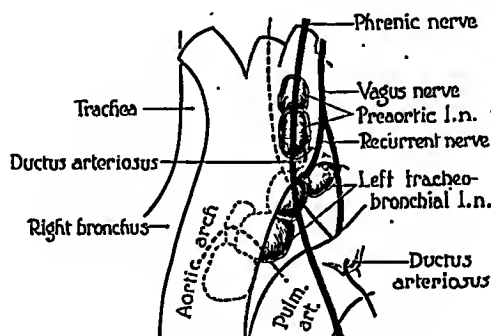


Fig. 18 (from cadaver).—Left phrenic nerve adherent to preaortic lymph nodes. The left recurrent nerve is seen between lymph nodes in the left tracheobronchial space.

probably not infrequent. Dorendorf<sup>8</sup> reported the case of a woman, aged 64, with pneumonia on the left side, who developed hoarseness due to paralysis of the left recurrent nerve. Necropsy revealed the left recurrent and the left vagus nerves surrounded by a gelatinous edema, and there were many swollen tracheobronchial lymph nodes.

CASE 8.—A woman, aged 37, had had suppurating cervical lymph nodes in her youth. At the age of 25, by accident a bit of cornflake had entered the larynx, precipitating a violent attack of coughing, with choking. Thereafter, whenever she took liquids, part was coughed up. She had regurgitation of food and thick mucus, epigastric pain, distress and vomiting, and she could not lie on the right side without pain or vomiting. Dyspnea was marked, increasing on exertion.

8. Dorendorf: Die Diagnose akutennicht eitrigen-und der chronischen Mediastinitis, Arch. f. Laryngol. u. Rhinol. 33:285-293, 1920.

CASE 2.—A woman, aged 24, had had influenza accompanied by pneumonia in 1918. Since the attack she had been troubled with a dry cough and frequent "colds." In May, 1921, she had had a chill and had noticed pain in the chest subternally, which increased on deep breathing and on swallowing either liquids or solids. She had dyspnea and dysphagia. The temperature for several days did not rise above 100. Her condition grew gradually worse and ten days later the pain in the chest became severe, and was also felt in the back between the shoulder blades. Hiccup developed. The temperature was 102.6. The dysphagia increased to such an extent that the patient could hardly swallow liquids and the dyspnea became extreme. The patient then had a severe coughing spell and



Fig. 6 (case 2).—Anteroposterior view: *a*, bifurcation; *b*, right bronchus; *c*, left bronchus; *d, d, d*, abscess in inferior tracheobronchial space; *e, e, e*, esophagus, and *f*, trachea.

expectorated three-fourths pint (354 cc.) of pus, with immediate relief. The highest leukocyte count was 30,200. In this case, the abscess originated in the lymph nodes of the inferior tracheobronchial space, where both main bronchi as well as the bifurcation were exposed to the pressure of the pent up pus, and the esophagus, as shown in the roentgenograms, was compressed to the almost complete occlusion of its lumen. In the anteroposterior view (fig. 6), a narrow streak of barium was seen to the left. In the oblique view (fig. 7), the column

one large oval opening by the sloughing off of the intervening strip of mucosa; this facilitated the entrance of food into the trachea. For that reason, four years after the phrenoplication, I made an anterior mediastinotomy by raising a flap containing the left part of the sternum down to the second interspace, the clavicle and the first and second rib, as described by Le Fort.<sup>9</sup> I loosened the adhesions down to the fistula without opening the latter. To repair the fistula did not seem feasible, and the chest was closed. During the year following this operation, the patient was in better health, her weight increased to 145 pounds (65 Kg.), and she coughed less. To what this improvement can be ascribed, I



Fig. 20 (case 8).—Esophagotracheal fistula, *a*.

do not know, unless that postoperative adhesions, by contraction, had decreased the fistulous opening or distorted it in such a way that food did not enter the trachea as readily as before.

One year after the last operation, she had an attack of influenza, after which severe cough developed with gradually increasing purulent expectoration, abdominal distress and vomiting. The vomiting gradually increased, and seven months later she could retain hardly any food. An exploratory laparotomy was made. Extensive adhesions were found in the right epigastric region between

9. Le Fort, R.: Une voie économique et large pour l'accès du carre-four cervico-médiastinal. *Presse méd.* 26:373 (July 22) 1918.

the trachea; below, the left tracheobronchial angle, and above, the aortic arch.

CASE 3.—A child, aged 3 months, one of twins, apparently had been well until the age of 6 weeks, although it had always been somewhat paler than its twin. Since the age of 6 weeks, it had not taken its feedings so well, and had ceased gaining in weight. Since the age of 7 weeks, it had been hoarse and had

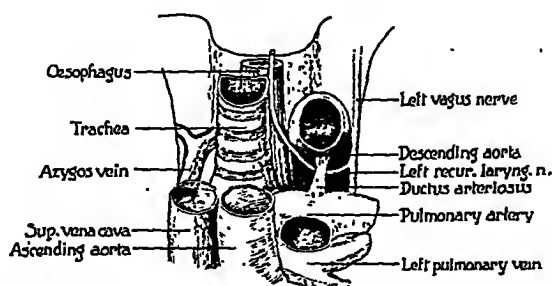


Fig. 8.—The left tracheobronchial space (Sukiennikow).



Fig. 9 (case 3).—Atelectasis of left lung due to pressure on the left bronchus.

wheezed and coughed. It coughed at each feeding and had frequent regurgitation. While in the hospital, the nurse noticed that when the baby was picked up it cried as if in pain, became cyanotic about the nose and mouth and coughed. There was always a great deal of mucus in its throat. Tube feeding was tried, but unless the tube was introduced toward the right, it met with an obstruction

The ulceration of suppurating tuberculous tracheobronchial lymph nodes into the trachea or bronchi is not rare. Schaldemose<sup>11</sup> compiled nineteen cases from the literature prior to the year 1900 and reported a case of his own. Schmiegelow<sup>12</sup> compiled twenty cases since the year 1900 and reported three cases of his own.

In this type of case immediate bronchoscopy is indicated for the purpose of diagnosis and for the removal of the debris from the caseous lymph nodes obstructing the respiratory passage. Schmiegelow also reported the case of a baby, aged 8 months, who died from an obstruction in the respiratory tract. Necropsy revealed a hyperplastic lymph node the size of a walnut compressing the trachea.



Fig. 22 (case 9).—Insufficiency of the left side of diaphragm.

In cases 1, 2 and 5, the patients dated the beginning of their trouble back to an attack of influenza. Although the literature on this question is scant, I believe that cases of mediastinal infection due to suppurating mediastinal lymph nodes, during and following the great epidemics of influenza, must have been of relatively frequent occurrence. This seems to be borne out by the observations of Dunham.<sup>13</sup> On examining the

11. Schaldemose, V.: Et tilfælde af bronchialglandeltuberkulose med perforation, helbredet ved tracheotomi, *Hospitalstid.* 14:22, 1902.

12. Schmiegelow, E.: Bidrag til bronchialglandeltuberculosens pathologi, *Hospitalstid.* 61:5, 1918.

13. Dunham, E. K.: Infection in the Mediastinum in Fulminating Cases of Empyema, *Surg. Gynec. Obst.* 25:288 (Sept.) 1922.



Fig. 11 (case 4).—Atelectasis of upper right lobe.



Fig. 12 (case 4).—Bronchoscopic view of compressed eparterial bronchus:  
*a*, upper wall; *b*, lower wall.

What part infected tracheobronchial or bronchopulmonary lymph nodes compressing a bronchus play in the etiology of bronchiectasis, and what part they play in the etiology of lung abscess; is well worth serious consideration:

In cases 7, 8 and 9 the diaphragm was affected. In each case, it was due to infected lymph nodes giving rise to acute nonsuppurative mediastinitis, which involved the left phrenic nerve. In an article published in 1922,<sup>14</sup> I classified cases of this condition of the diaphragm as congenital and acquired cases, subdividing the latter into acute and chronic, and I suggested the name "insufficiency" of the diaphragm instead of the name "eventration." Insufficiency means incapacity for normal action, while the name eventration of the diaphragm has no reference to the condition of the diaphragm itself. In case 9, I saw the left side of the diaphragm in the normal state, in the acute stage of insufficiency and in its return to normal. In case 7, I saw the diaphragm when normal, and also in the acute stage, but it had not returned to normal when observed five years later. In case 8, the insufficiency was chronic.

Under the name anterior mediastinodiaphragmatic lymph nodes, Bartels<sup>6</sup> describes the lymph nodes situated where the phrenic nerve enters the diaphragm and a group of nodes near the inferior vena cava. These nodes receive lymph vessels from the liver and the diaphragm.

CASE 9.—A man, aged 38, had been doing well after a posterior gastroenterostomy for duodenal ulcer and an appendectomy, until the eighth day after the operation, when he felt nauseated and had an emesis. On the ninth day, hiccup developed and continued for three days, at times severe. The nausea and the vomiting ceased three days later. The patient was discharged on the nineteenth day after the operation. The temperature at no time exceeded 100 F. On fluoroscopic examination, the left side of the diaphragm was seen at a higher level than the right (fig. 22), and on expiration it reached the third interspace. This condition of the diaphragm lasted several weeks; it gradually came down to the normal level in about eight weeks after the onset. Roentgenograms taken before the operation showed a normal diaphragm.

Subdiaphragmatic infection occasionally follows abdominal operations, especially operations on the vermiform appendix. As the anterior mediastinodiaphragmatic lymph nodes receive lymph from the liver and the diaphragm and are close to the phrenic nerve where this enters the diaphragm, an infection of these nodes with a localized acute nonsuppurative mediastinitis would involve the nerve and account for the condition of the left side of the diaphragm. There is, however, another avenue by which infection from the abdomen may enter lymph nodes in close contact with the phrenic nerve. Küttner,<sup>15</sup> in injecting the lymph

14. Lerche, W.: *Insufficiency (Eventration) of the Diaphragm*, Surg. Gynec. Obst. **34**:224-229 (Feb.) 1922.

15. Küttner, H.: *Die perforierenden Lymphgefäße des Zwerchfells und ihre pathologische Bedeutung*, Beitr. z. klin. Chir. **40**:136, 1903.



Fig. 14 (case 5).—Anteroposterior view: *a*, abscess cavity in posterior mediastinum; *b*, fistula to the esophagus; *c*, *c*, barium mixture in bronchi, and *d*, fistula to the right lung.

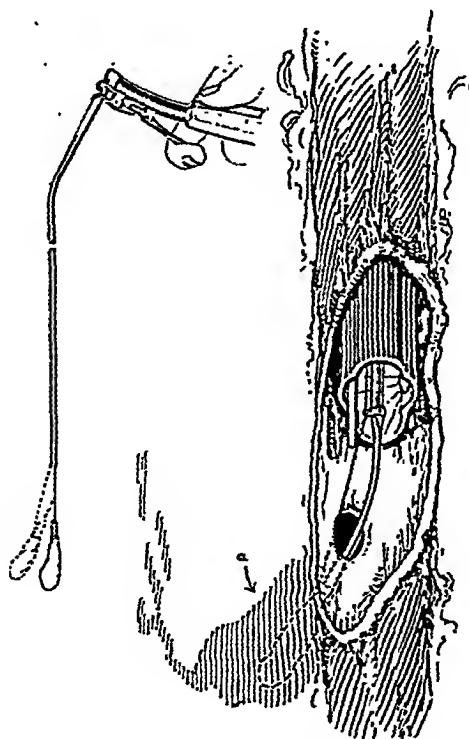


Fig. 15 (case 5).—Method of making applications to the mediastinal abscess cavity, *a*, through the esophagoscope.



# HERNIAS OF THE MEDIASTINUM DURING THE COURSE OF ARTIFICIAL PNEUMOTHORAX

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When air gains access to the pleural cavity a displacement of the mediastinum frequently takes place. This mobility of the mediastinum depends on the flexibility of its tissues, the lack of pleural or pleuro-pericardial adhesions, the pressure created within the pleural space and the size or volume of the pneumothorax. The entire mediastinum may be displaced or a part of it. Thus, only the upper or only the lower portion may be displaced. Besides these variations in the position of the mediastinum, a protrusion of the pneumothorax cavity through the mediastinum into the sound, or untreated, side, occasionally takes place, forming a culdesac, or hernia. The most frequent point for a hernia of this nature to occur is in the upper anterior part of the mediastinum between the first and third ribs. Here the right pleura and left pleura come in closest contact and are separated only by a small amount of areola tissue; the junction represents the weakest point in the mediastinal barrier. The lower posterior part of the mediastinum between the fifth and the tenth dorsal vertebrae is another weak spot.

The hernia may be small and protrude only slightly into the sound side, or so large as to form a distinct localized pneumothorax.

The cases reported here illustrate the various types of mediastinal hernia.

## REPORT OF CASES

CASE 1.—H., a man, aged 34, had had the right lung successfully collapsed by artificial pneumothorax in February, 1924. The mediastinum had been mobile. There had been no effusion and the clinical results had been excellent. The average refill had been 600 cc. every two weeks. The average pressure before refill had been  $-6-3$ ; after refill,  $0+2$ . After one year of collapse therapy, the patient had complained of pain in the upper part of the left side of the chest and some shortness of breath shortly after the administration of gas.

Examination showed dull tympany over the entire right side of the chest and extending 1 inch (2.5 cm.) beyond the left margin of the sternum in the region of the second rib. The area was devoid of breath sounds. The left border of this zone was defined by the exaggerated respiratory sounds of the left lung. On fluoroscopic examination, a high light was seen extending about 2 inches (5 cm.) beyond the left border of the sternum, its clearly defined edge describing an arc from the first to the third rib. On deep inspiration, the high light moved toward the pneumothorax side and became lost in the shadow of the mediastinum, only to reappear on expiration. This to-and-fro movement of the hernia during respiration is a startling fluoroscopic picture.

CASE 6.—A man, aged 72, had been in good health until six weeks before consultation, when a piece of meat had become impacted in the lower part of the esophagus. The meat finally had been regurgitated, but since the accident the patient had had pronounced dysphagia and a great deal of pain in the lower part of the left side of the chest, radiating to the back, with hiccup and nausea but no vomiting.

Through the esophagoscope, I saw a small ulcerating growth in the lower third of the esophagus, posteriorly to the right, with an opening in the center from which pus exuded. Biopsy showed adenocarcinoma. A roentgenogram (fig. 16) showed a cavity in the posterior mediastinum communicating with the esophagus. These observations were corroborated by necropsy. The presence of



Fig. 17 (case 7).—High position of left side of diaphragm.

the meat probably favored infection that was carried to the lymph nodes in the posterior mediastinum; an abscess formed and broke through the center of the small carcinoma in the esophageal wall.

The preaortic lymph nodes are situated on the anterior surface of the aortic arch.

CASE 7.—A girl, aged 16 years, had had a cough for two weeks when seen in May, 1920. There was a friction rub over the pleura on the left. The chest was examined fluoroscopically, and the diaphragm was seen functioning normally. In March, 1921, she had repeated attacks of hiccup and pain behind the upper part of the sternum. She also complained of a choking sensation and fulness after taking even small amounts of food. On fluoroscopic examination, the left

refill had been  $-7-3$ ; after refill,  $-3-1$ . In March, 1924, the patient had developed a pleural effusion. It was ushered in with severe symptoms, pains in the right side of the chest, fever, vomiting and urgent dyspnea. On March 15, 600 cc. of turbid fluid had been withdrawn.

On entrance, the pressure above the level of the fluid was  $+1$  to  $+3$ . After paracentesis and replacement with air, the pressure was left at  $-5$  to  $0$ . Two weeks later, a roentgenogram of the chest showed a fairly well collapsed right lung and the mediastinum moderately displaced; between the first and fifth ribs



Fig. 2 (case 1).—Outline of hernia not seen, during full inspiration. The swing of the mediastinum and the collapsed lung should be noted in comparison with figure 1.

a well defined hernia bulged into the left side of the chest in front of the heart and trachea. A fluid level was seen at the fifth rib on the right and extended over into the hernial sac.

The physical signs usually elicited over a pneumothorax extended across the sternum into the left side of the chest over the zone of the hernia. Succussion sounds were heard in the normal cardiac area.

While the hernia existed, the patient had marked dyspnea, a rapid pulse, uncomfortable cardiac sensations and pain beneath the lower part of the sternum radiating to the back. By the occasional aspiration of fluid and replacement with

Fluoroscopic examination showed that the upper limit of the left side of the diaphragm was on a level with the third interspace, the fundus of the stomach was distended by an enormous gas bubble, and the heart was displaced to the right (fig. 19). When the patient swallowed the barium mixture, part of the latter was seen flowing into the bronchi on both sides. This phenomenon was due to an esophagotracheal fistula (fig. 20). The fistula was found to be 19 cm. from the incisor teeth, as measured in bronchoscopy and esophagoscopy. I believe that in this case the insufficiency of the left side of the diaphragm, the so-called eventration, was acquired and due to degeneration of the left phrenic nerve following inflammation of the nerve by extension from infected lymph



Fig. 19 (case 8).—Left side of diaphragm, *a*, and barium mixture in bronchi, *b*, *b. b.*

nodes, probably the preaortic group. The esophagotracheal fistula was caused by suppurating tracheal lymph nodes ulcerating through the walls of the esophagus and trachea, the abscess rupturing during the violent coughing spell.

I made a phrenoplication of the left side of the diaphragm (fig. 21), which relieved the patient of her dyspnea and gastric symptoms; for a while she coughed less. In time, the cough became more troublesome, and I attribute this to the fact that the fistula on the esophagus side, which originally had two openings, separated by a narrow strip of esophageal mucosa, became converted into

right, the fluid ran from the hernia into the pneumothorax side, the neck of the sac being in front of the great vessels of the heart. My case 2 was like von Muralt's, but the hernia and the exudate did not attain such large proportions.

Kellner<sup>3</sup> describes a case in which at necropsy two large culdesacs of a left-sided pneumothorax were found bulging in front of the heart into the right side of the chest. An exudate was present. It was



Fig. 4 (case 3).—Large hernia of the anterior part of the mediastinum.

thought that the hernia was the cause of death—by embarrassing the heart action and limiting the function of the sound lung. My case 3 was somewhat similar, the patient had cardiac and respiratory distress but escaped death.

Eggers<sup>4</sup> has recently reported a case of pyopneumothorax which pushed through the anterior mediastinum to form an enormous hernia

3. Kellner: Beitr. z. Klin. d. Tuberk. 54:405, 1923.

4. Eggers, Carl: Lung Abscess Complicated and Hidden by Empyema, Arch. Surg. 12:338 (Jan.) 1926.

the stomach, liver, omentum, coils of the intestines and the anterior abdominal wall. A gastro-enterostomy gave no relief.

Necropsy was performed by Prof. E. T. Bell. Except for the adhesions mentioned, no lesion of the abdominal organs was found. The diaphragm reached the fourth rib on the right and the fifth rib on the left. The left pleural cavity was obliterated by adhesions. The tracheobronchial and other mediastinal lymph nodes were markedly enlarged on the left side, but normal on the right. There were adhesions in the upper part of the mediastinum. There was no gross evidence of tuberculosis of the lungs, but there was bronchiectasis of the lower left lobe. The esophagotracheal fistula was oval and measured 10 by 6 mm. The extensive adhesions in the right upper abdominal quadrant, in the absence of organic lesions or surgical intervention in this region and with the symptoms coming on

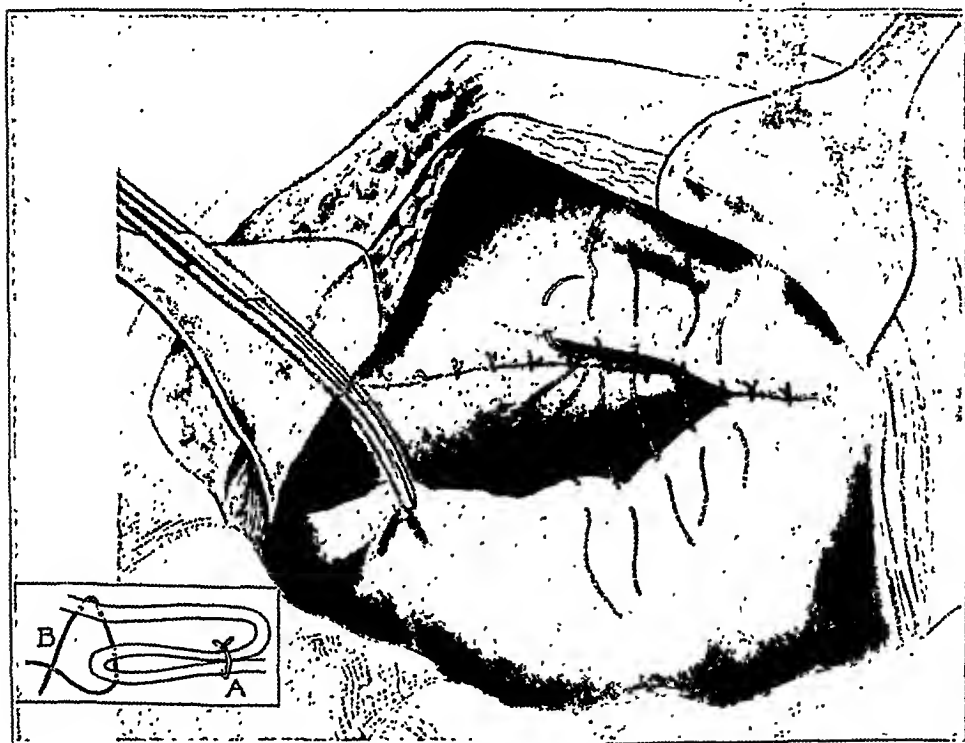


Fig. 21 (case 8).—Phrenoplication.

after the attack of influenza, may be ascribed to infection after influenza. The diaphragm was removed in its entirety. On gross inspection, no trace of the phrenoplication was seen. The left side of the diaphragm had held its place since the operation, and the patient thereby had been relieved of distressing symptoms.

Dalziel<sup>10</sup> reported a case of a large abscess from tuberculous lymph nodes under the arch of the aorta in which he had successfully operated, and he refers to two similar cases of his in which operation was performed with satisfactory results. These abscesses probably originated in the preaortic in the tracheobronchial lymph nodes on the left.

10. Dalziel, T. K.: Tuberculous Glands in the Anterior Mediastinum; Operation, *J. Laryngol. Rhinol. & Otol.*, 1915, p. 83.

4. The average age of the patients was 23 years, youth favoring a flexible mediastinum.

5. Pressures in the earlier reported cases were high (+ 8 + 14) but in the later cases never above + 1 or + 2.

6. Refills (when reported) were large, between 500 and 1,000 cc. at intervals of from ten days to two weeks.

7. An effusion was present in thirteen cases.



Fig. 6.—Large hernia of anterior part of mediastinum in a case of spontaneous pneumothorax complicating artificial pneumothorax. The position of the heart and the bronchus behind the hernia should be noted.

8. Dyspnea was the chief symptom produced by the hernia. A few complained of slight pains in the region of the hernia. In the four cases in which the hernia bulged in front of the heart and an effusion was present, there was marked cardiac and respiratory distress, followed by death in one instance.

9. In the cases so reported, when the hernia was once "reduced," it did not reappear again, and the symptoms were ameliorated.

records of 3,889 cases of nontraumatic empyema in the United States Army, he found that sixty-seven cases of acute mediastinal infection had been noted in 531 necropsies. Many of these cases were associated with postinfluenzal and postmeasles empyema. In the examination of the mediastinal lymph nodes apparently had not been made, but he mentions one case thus examined and in that streptococcus was demonstrated.

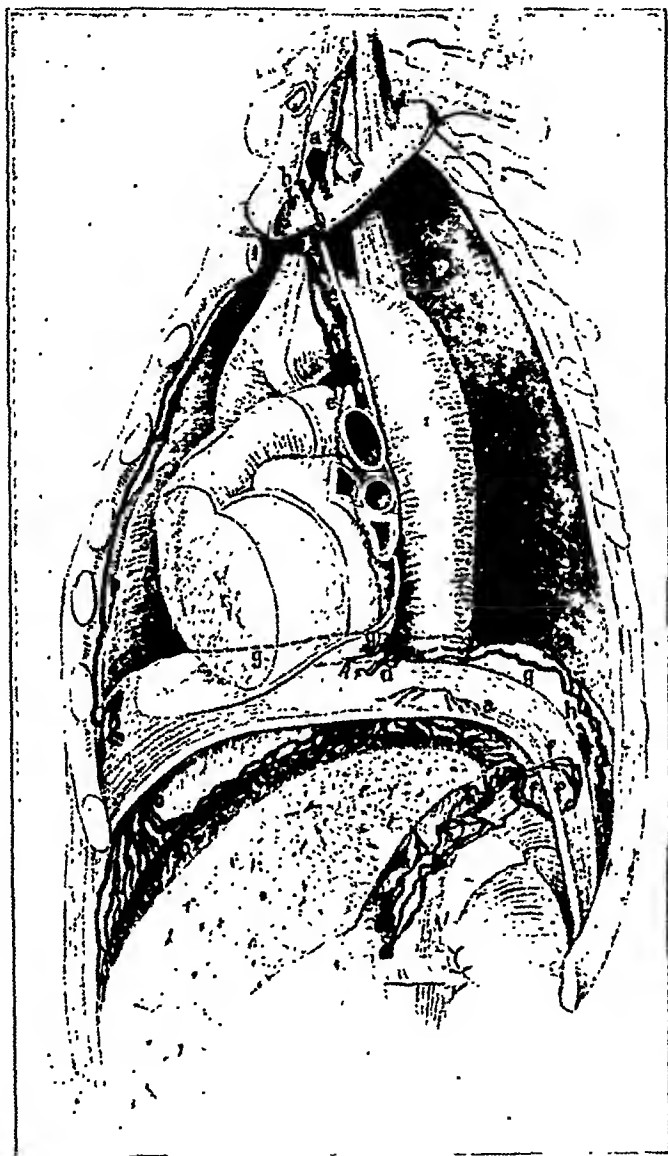


Fig. 23 (case 9).—Lymph nodes, *c c*, on the left phrenic and vagus nerves and the aorta.

Dunham also mentions a case of empyema on the right with purulent pericarditis, the latter secondary to mediastinitis. At the tracheal bifurcation was a mass of glands about the size of two fists, from which a tract led to the pericardium, which held a quart (946 cc.) of pus.



ably sufficient to break the mediastinal barrier, and a hernia results. I doubt if a hernia could be produced in the presence of a small pneumothorax.

Why the hernia expands and contracts may be explained as follows: If the chest wall and diaphragm undergo reasonably full respiratory excursions and if the collapsed lung varies but little in volume, then something must "give" for the reason that the volume of the pneumothorax is constant and is not subject to variations through passage of air by way of the trachea. Therefore, during expiration the mediastinum moves over as the diaphragm rises, and the chest wall falls in and the hernia bulges into the sound side. On inspiration, the reverse takes place, and the hernia is sucked back as the diaphragm sinks and the chest wall opens.

Graham and Bell,<sup>6</sup> in their experiments on the dog, showed that when an opening was made through the chest wall which permitted less air to enter the pleural cavity during inspiration than entered the lungs by way of the trachea, the animal was able to compensate for the loss of lung volume produced by the pneumothorax by deeper respiratory excursions, and the lung on the affected side was seen to expand and contract. When, however, a large opening was made, during the few minutes the animal remained alive, the mediastinum was seen to flap from side to side with each inspiratory and expiratory movement, and it sometimes happened that with a severe expiratory effort the anterior part of the mediastinum was ruptured so that a double pneumothorax occurred. In patients with a mediastinal hernia, a somewhat analogous condition is present. The pneumothorax, of course, is a closed one, but the air volume within the pleural cavity is large, and the patients by their dyspnea show a failure to compensate fully for loss of lung volume; in three instances reported in the literature, there was a rupture of the mediastinum and the production of a double pneumothorax.

The factors causing a mediastinal hernia are, fortunately, not frequently found in perfect combination. In the majority of patients undergoing therapeutic collapse, the mediastinum is rigid; or the lung is adherent at various places; or the diaphragm and chest wall on the pneumothorax side are practically immobile, or, if movement does take place, it is compensated for by variations in the volume of the collapsed lung during respiration.

Of what clinical significance are these hernias? The majority of patients exhibiting a small or medium sized hernia complain only of slight chest pains and moderate shortness of breath. As mentioned in the foregoing, the large hernias may cause distressing symptoms or even death.

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6. Graham, E. A., and Bell, R. D.: *Am. J. M. Sc.* **156**:839 (Dec.) 1918.

vessels of the falciform ligament of the liver in a cadaver, found that although some of the vessels ended in the supraclavicular lymph nodes, the majority turned into the mediastinum at the level of the first rib, and after passing through a lymph node lying on the phrenic nerve crossed the triangular space between the latter and the left vagus, where they ended in a large lymph node on the aorta and the anterior aspect of the vagus (fig. 23 c, c). An inflammation of these nodes might give rise to an acute nonsuppurative mediastinitis affecting the phrenic nerve. Although the latter route of the infection from the abdomen by way of the subdiaphragmatic space is possible, I believe that the infection of the phrenic nerve in this case took place through the anterior mediastinodiaphragmatic nodes.

#### CONCLUSIONS

1. There is considerable discrepancy in the anatomic literature in regard to the topography, the number and the nomenclature of the mediastinal lymph nodes.
2. The mediastinum seems remarkably tolerant to infection.
3. The bronchoscope and the esophagoscope are of great aid to the thoracic surgeon in diagnosis as well as treatment; in the diagnosis of suppuration in the tracheobronchial spaces referred to in the foregoing they are indispensable.
4. I believe that the future specialist in thoracic surgery will find it necessary to be an expert in bronchoscopy and esophagoscopy.

#### ABSTRACT OF DISCUSSION

DR. EDWARD W. ARCHIBALD, Montreal: The reports made by Dr. Lerche in the last two or three years indicate that he is qualified to teach precision in diagnosis of obscure conditions in the mediastinum and their anatomic situation. Some years ago when I had a case of this kind, I was confused, and I found that every one else was as confused about mediastinal infections and abscess as I was. I had one case, which I think I mentioned when Dr. Lerche read his last paper on the subject, in which the communication made by the breaking through of an abscess was betrayed by a gas bubble rising above the shadow; this, of course, was caused by the abscess in the neck. This abscess was not only in one but in both sides of the neck.

# EVENTRATION OF THE DIAPHRAGM

DIAGNOSIS AND TREATMENT, WITH A REPORT OF FOUR CASES

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Eventration of the diaphragm is a rare anomaly of obscure origin characterized by the permanent high position of one leaflet of the diaphragm and the displacement into the thorax of the abdominal viscera on the affected side.

Bamberger<sup>1</sup> in 1913 compiled thirty-one cases. Bayne-Jones<sup>2</sup> gathered forty-four from the literature and added one of his own. Korns<sup>3</sup> critically reviewed the reported cases and regarded twenty-two as proved and forty-three as probable, giving a total of sixty-five certain or probable cases to 1921. A number of cases have since been reported. Four have come under observation at the Massachusetts General Hospital in the course of 16,504 roentgen-ray examinations of the chest.

## IMPORTANCE OF EVENTRATION

The number of patients with eventration of the diaphragm likely to come under the observation of any one person is small. Recognition of the existence of such a group of cases is important, however, to prevent confusion with other intrathoracic conditions. Without the assistance of the roentgen ray, eventration of the diaphragm has been mistaken for pleural effusion, and exploratory thoracentesis and thoracotomy have been performed. The anomaly is chiefly of importance, however, on account of the readiness with which it may be confused with diaphragmatic hernia, and differentiation between these two conditions may be impossible even after resort to all available safe methods of investigation, short of exploratory laparotomy.

Eventration of the diaphragm is important also from an entirely different point of view. Within the last few years there has been an increasing tendency to resort to phrenicotomy in the treatment of pulmonary tuberculosis, for the purpose of supplementing the usual hygienic-dietetic regimen or as a preliminary to a more radical surgical procedure. Unilateral phrenic paralysis produced by the surgeon displaces thoracic and abdominal organs as in the anomaly with which we

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1. Bamberger: *Ergebn. d. inn. Med. u. Kinderh.* **12**:327, 1913.

2. Bayne-Jones, S.: *Eventration*, *Arch. Int. Med.* **17**:221 (Feb.) 1916.

3. Korns, H. M.: *Diagnosis of "Eventration" of Diaphragm*, *Arch. Int. Med.* **28**:192 (Aug.) 1921.

The discovery of the hernia led to a reduction in the amount of gas administered, and as a consequence the hernia gradually disappeared. The vesicular murmur of the sound left lung is now heard to the midline of the sternum.

CASE 2.—N., a man, aged 24, had had the right lung well collapsed by artificial pneumothorax in April, 1923. The mediastinum had been mobile. The average refill had been 700 cc. every three weeks. The pressure before refill had been  $-6 -4$ ; after refill,  $-3 -1$ . In January, 1924, he had developed a slight pleural effusion without local or constitutional symptoms. In February, 1924, a



Fig. 1 (case 1).—Small hernia of the mediastinum during forced expiration. Comparison should be made with figure 2.

mediastinal hernia was first noted between the first and the third ribs, and at this time shortness of breath occurred. The hernia was larger than the one observed in the previous case, and contained a small amount of fluid. This hernia showed a to-and-fro movement but did not entirely disappear at the height of inspiration. With a reduction in the amount of gas administered, the dyspnea was relieved and the hernia soon disappeared.

CASE 3.—H., a man, aged 29, had had the right lung collapsed by artificial pneumothorax in October, 1923. The mediastinum had been mobile. The average refill had been 700 cc. every two or three weeks. The pressure before

in the middle of the right side of the chest in front, lasting from fifteen to thirty minutes. The pain radiated to the upper part of the right side of the chest and forearm. It came without warning, usually in the late morning, was unrelated to exertion and was increased by a long breath. He was short of breath during the attacks. In addition, for the last four years he had had a constant burning pain across the front of the chest, aggravated by taking a long breath and relieved by lying down. During the more severe attacks of pain, he had a dry cough, which subsided after a few hours rest in bed. Ordinarily there were no gastrointestinal symptoms, but during periods of more severe thoracic pain he was unable to eat on account of distress in the left hypochondrium. He felt this about half an hour after eating, and it lasted for from one to two hours. Ten years before examination, for a period of three days he had had abdominal pain, distention, nausea and vomiting, with no bowel movement during this time. There had been no fecal vomiting. He was much incapacitated for work and spent an average of perhaps from ten to twelve days in bed each month.

The patient was well developed and nourished. The chest was symmetrical, and expansion of the two sides was equal. The left side was dull in front below the fifth rib, and behind from a short distance below the angle of the scapula to the base. There was no tympany. The breathing was much diminished, without bronchial quality, voice sounds were diminished and without egophonic quality, and the tactile fremitus was absent over the dull area. There was no succussion splash.

Roentgen-ray examination showed the dome of the left side of the diaphragm of unbroken contour opposite the anterior portion of the third rib. With forced inspiration there was slight reversed excursion. The right side of the diaphragm was normal. The heart and mediastinal contents were displaced toward the right. Barium was seen to pass through the esophagus in the usual manner, and showed the stomach lying below the diaphragm.

The sudden onset of symptoms after sneezing twenty years before and their character in the succeeding years suggested diaphragmatic hernia rather than eventration. The roentgen-ray report, however, was consistent with eventration.

CASE 2.—M. A. J., a married woman, aged 55, seen Aug. 23, 1926, for the last three years had been short of breath and unable to climb more than four stairs without dyspnea. She was unable to lie on the right side without dyspnea, but could lie comfortably on the back and left side. There had been slight wheezing with exertion and on lying down for two years. She had had a cough for three years, daily raising about one-half teaspoonful of white sputum without blood.

For three years there had been attacks of nonradiating, dull, aching pain to the right of the midline in the epigastrium, lasting from one to two minutes and recurring about once daily, usually at night on lying down. This pain had been severe enough to double her up and make her groan, but not to keep her awake. The appetite had been poor. Nausea had been troublesome at varying intervals for five months. There had been no vomiting and no distress after eating. The bowels moved daily. She was not especially troubled by gas.

For the last five months she had had "dizzy, sinking" spells once or twice a day, lasting for about half an hour. She slept poorly and passed urine from two to three times at night. The maximum weight was now 143 pounds (64.9 Kg.); her height was 5 feet, 3 inches.

small amounts of air, the symptoms were gradually ameliorated. In August, 1924, roentgen-ray examination showed that the mediastinum occupied its normal position and that the hernia had entirely disappeared. It is interesting that in this case the pleural pressures were never found above  $+3$ . Usually, they were less than zero.

Brauer<sup>1</sup> reports a case in which the hernia involved the lower posterior part of the mediastinum. The pneumothorax was on the right side.



Fig. 3 (case 2).—Medium sized mediastinal hernia containing small amount of fluid.

the culdesac to the left. The fluid level of an effusion crossed in front of the spinal column. This hernia is the only one I have found reported that occurred at this site.

Brauer and Spengler<sup>2</sup> report a case of von Muralt's of a large, pouchlike hernia containing fluid. When the patient was tipped to the

1. Brauer: *Handbuch der Tuberculose*, ed. 3, vol. 2, p. 489.

2. Brauer and Spengler: *Beitr. z. Klin. d. Tuberk.* 19:1, 1911.

On auscultation the breath sounds were much diminished (not bronchial) over the upper half and absent over the lower half of all parts of the dull area in the left side of the chest. Gurgling sounds resembling those due to intestinal peristalsis were heard below the left third rib in front and the midscapula behind. No râles were heard. The voice sounds were diminished over the upper and absent over the lower half of the dull area. No egophony was heard, no whisper throughout, and no succussion splash. Tactile fremitus was absent throughout the dull area.

The cardiac impulse was not seen or felt. The heart sounds were regular and of good quality. No murmurs were heard. The cardiac sounds were louder to the right than to the left of the sternum. By percussion the right border of the heart was one finger breadth inside the right nipple line.

Examination of the right lung was negative throughout.

Roentgen-ray examination showed the dome of the diaphragm to be on the left side opposite the third rib in front. Its outline was smooth. Respiratory motion was normal, but somewhat limited in amplitude. The heart and mediastinal shadow were displaced to the right. There were no movements of the mediastinum with respiration. Below the diaphragm shadow the gas filled fundus of the stomach was seen, after the administration of barium by mouth. External to this was the shadow of the colon, identified by barium enema. There was no evidence of dilatation of the colon. The splenic flexure was seen lying along the greater curvature of the stomach and in contact with the elevated diaphragm. The lumen of the bowel was normal throughout.

The symptoms and the results of physical and roentgen-ray examinations were consistent with eventration of the diaphragm. The exaggerated inspiratory excursion of the left side and the exaggerated inspiratory divergence of the left costal margin were noteworthy and of probable diagnostic significance.

In the two following cases the symptoms were insignificant:

CASE 3.—F. D., a barber, aged 33; married, who was seen Aug. 30, 1926, had visited the Massachusetts General Hospital at intervals during the three years ending three years before. He had complained of fatigue and a sense of "weakness in the left side of the back," gastric flatus, rumbling noises in the left side of the upper part of the abdomen and in the left side of the lower part of the chest in front, constipation and vague pains in the left upper quadrant of the abdomen, associated with gas and relieved by belching and passage of gas by rectum and by defecation. Fatigue at his work as an edge trimmer in a shoe factory appears to have been a factor in his symptoms, which would disappear when he stopped work. There had been no other significant symptoms and no complaints for the last three years. There had been no dyspnea, cough, wheezing or pain in the chest.

On examination the patient was found to be well developed and well nourished. The chest was symmetrical. The circumference of the left half of the chest was 39 cm.; of the right, 38.5 cm. With the patient on his back, the inspiratory expansion of the two sides of the chest as a whole was the same, but there was an exaggerated divergence of the left costal margin from the median line in the epigastrium with consequent greater widening of the left than of the right side of the subcostal angle. There was inspiratory retraction of the epigastrium. On percussion, the left side of the front of the chest was dull below the second rib and the left side of the back was dull below the spine of the scapula. The

in the left side of the chest. A roentgenogram of the patient taken in the erect position, but inclined to the right, showed the fluid level running across the entire thorax.

#### SUMMARY OF REPORTED CASES

A review of the thirty-nine cases of mediastinal hernia, including nine of my own, reported in the literature shows:



Fig. 5 (case 3).—Posterior view, showing exaggerated appearance of hernial sac.

1. That in only one instance was the lower part of the mediastinum involved posteriorly, the rest being involved anteriorly—thirty-four between the first and third ribs, and four between the first and fifth ribs.

2. In twenty-four cases, the pneumothorax was left-sided, the hernia being to the right; in fifteen, the pneumothorax was on the right side and the hernia to the left.

3. In all cases, the mediastinum was displaced to a greater or less degree.



by upward displacement or if its musculature is impaired, the pull of the intercostal muscles is accentuated.

There are few cases in the literature in which sufficient attention has been paid to respiratory motion in the presence of eventration of the diaphragm to test the diagnostic value of Hoover's observations. The reports by Funk,<sup>6</sup> Korns<sup>3</sup> and Reifenstein,<sup>7</sup> however, support Hoover's contention and indicate that important evidence may be obtained by simple inspection of the chest. In a case with eventration of the left side of the diaphragm, Funk found distinct inspiratory widening of the subcostal angle due principally to a greater divergence of the left costal border. Korns, in a case of right-sided eventration, noted marked diminution in the undulatory movement of the right upper five ribs and distinct impairment in the excursion of the arches of the lower seven ribs; with the patient recumbent, there was an inspiratory divergence from the median line of the entire right costal margin from the xiphoid to the posterior axillary line in excess of that on the left side. In Reifenstein's case, with left-sided eventration the upper and lower costal margins on the left side moved outward more than on the right. As already noted in the report of the cases I have seen, the respiratory movements in two (cases 2 and 3) were similar to those to be expected from Hoover's observations and like those seen in the cases reported by the authors just mentioned. In the other two cases, no observations were made on this matter. From the evidence presented by these five cases, Hoover's signs would seem to be of importance in the diagnosis of eventration of the diaphragm.

Hoover<sup>8</sup> attributes even greater importance to the signs just mentioned than these cases would indicate. In comment on Funk's<sup>6</sup> article, he stated that the observation of increased movement of the costal margin on the affected side would be of service in the differentiation between hernia and eventration, and that in hernia the movement of the costal margin was not modified. This difference in the behavior of the diaphragm in the presence of hernia is explained by Korns<sup>3</sup> on the ground that in this condition the diaphragm is not aplastic and in a high position, but has intact muscles and an approximately normal position. From the physical signs Hoover was able to make the diagnosis of hernia of the left side of the diaphragm in Korns' second case, in which by fluoroscopic examination the stomach was seen to lie almost entirely in the left pleural cavity.

These observations are of great importance in view of the difficulty of distinguishing between diaphragmatic eventration and hernia by

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6. Funk and Manges: *M. Rec.* 98:289, 1920.

7. Reifenstein, E. C.: *Am. J. M. Sc.* 169:668 (May) 1925.

8. Hoover, C. F.: *Tr. A. Am. Phys.*, 1920, vol. 35.

Fluoroscopically, the view of a mediastinal hernia is startling, for one sees a high light with a dark, curving border expand and contract, as it were, with each respiratory excursion; on deep inspiration, it merges with the dense shadows of the mediastinum, and on expiration it protrudes into the sound side. During the expiratory phase, the mediastinum also swings to the healthy side with elevation of the diaphragm. The hernia may be seen more clearly if the patient is rotated slightly, so that an oblique view of it may be obtained. If the patient is examined fluoroscopically from the back, the hernia assumes larger proportions on the screen because of its location in the anterior part of the mediastinum. It is thus brought closer to the roentgen-ray tube.

The roentgenogram reveals the high light with a curved border in front of the trachea and heart shadows. The exaggerated appearance of the hernia when taken in the posterior view must be kept in mind, for it may be misinterpreted as a hernia of the posterior mediastinum.

No doubt many small mediastinal hernias are missed in the roentgenogram because, as a rule, chest exposures are taken at full inspiration, at which moment these hernias are reduced to their minimum size. To obtain the best roentgenogram of a hernia, the exposure should be made at deep expiration.

A mediastinal hernia may be mistaken for an intrapulmonary cavity.

Nitsch<sup>5</sup> showed that there are two "weak spots" in the mediastinum. The first or upper lies between the first and third ribs as the site of the atrophied thymus. By creating a pneumothorax in the cadaver on one side of the chest, he could produce a hernia at this spot. The second, or lower, weak spot lies posteriorly between the fifth and the tenth dorsal spines. Sauerbrach has pointed out the rarity of hernias at this place, and that when they do occur they are from right to left. Nitsch has shown schematically that a hernia at this site may bulge from right to left between the aorta and the esophagus, but that when pressure is brought to bear on these structures from the left pleural cavity, the esophagus overlaps the aorta and thus makes an effectual barrier.

#### COMMENT

A large pneumothorax is a factor found in all patients who have a mediastinal hernia. The mediastinum is displaced, and the diaphragmatic leaf is low. The pneumothorax assumes large proportions because the nonrigid mediastinum offers little resistance to the introduction of excessive amounts of air. The intrapleural pressures may always be negative. It is this displacement of the mediastinum that seems to "uncover" its weak spot, permitting the pneumothorax to push through at an advantageous moment. The act of coughing or straining is prob-

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5. Nitsch: Beitr. z. Klin. d. Tuberk. 18:1, 1911.

in the literature, and this indicates that one might easily be led astray in the interpretation of the curves. Minkowski,<sup>12</sup> in a case of eventration of the diaphragm, found on manometric determination of the intragastric pressure an inspiratory fall with costal breathing and an inspiratory rise of pressure with abdominal breathing. Observations of the respiratory pressure relations in the stomach herniated through the diaphragm are needed to determine the truth of the assumption that they are the reverse of those found in the normally placed stomach before the merits of this procedure can be estimated.

Roentgen-ray examination is practically always necessary to establish the diagnosis of eventration of the diaphragm or of diaphragmatic hernia. It is indispensable also, but cannot always be relied on, in the differentiation between eventration and hernia.

In the presence of eventration, roentgen-ray examination shows the high position on one side of an unbroken arched line resembling the dome of an elevated diaphragm, and below it toward the median line a shadow resembling that of the gas-filled fundus of the stomach. External to this are shadows consistent with those due to the colon. The identity of the stomach and colon may readily be established by roentgen-ray examination after administration of barium by mouth and a barium enema. The heart and mediastinal shadow are likely to be displaced to the opposite side, usually the right side.

A difficulty in the roentgen-ray examination is the identification of the arched line as the shadow of the elevated diaphragm. That it cannot always be so regarded is indicated by the observations in Lotze's<sup>13</sup> case, in which on the left side a sharply arched line was seen reaching upward to the third rib. Lotze's clinical diagnosis of relaxation of the diaphragm was disproved at necropsy, which showed a diaphragmatic hernia and the stomach, a large part of the transverse colon and the great omentum in the left pleural cavity. Although an unbroken arched line is essential for the diagnosis of eventration, it cannot be regarded as a distinctive sign of this condition.

The relation of the affected diaphragm to respiratory motion, immobility, normal or paradoxical movement has no diagnostic value in the differentiation of eventration from hernia. Respiratory excursion of the mediastinum was absent in case 2 reported here. In case 3, there was movement toward the affected side with inspiration and toward the opposite side with expiration. Otten and Schefold<sup>4</sup> made a similar observation in their case. Korns<sup>3</sup> rejects this case from the category of eventration on the ground that the observation implies a greater negative intrapleural pressure on the left than on the right side, and he cannot

12. Minkowski: *Berl. klin. Wchnschr.* 54, 1917.

13. Lotze: *Deutsche med. Wchnschr.* 40, 1906.

The danger of rupture of a mediastinal hernia is illustrated by the following case reported by Walsh:<sup>7</sup>

A man, aged 22, had had a right-sided collapse, beginning May 11. From then until July 14, he received 6,300 cc. of air, or an average of 500 cc. every five days. One month later he died. The clinical diagnosis at death was right-sided artificial pneumothorax and hydrothorax, and left-sided spontaneous pneumothorax. Before the chest was opened, the manometer showed a pressure of +2 on the right side and +8 on the left. Necropsy revealed 900 cc. of serous effusion in the right pleural cavity; the liver border below the umbilicus, and the diaphragm at the sixth rib on the right and the seventh rib on the left. The heart was displaced to the left. There was a pneumothorax on the left side. The right lung was compressed to about one-fourth its normal size. He stated that the right parietal pleura was distended over the left lung to the anterior axillary line to a point just above the horizontal mammary line, gradually receding above and below. He gave the cause of death as artificial pneumothorax on the right, which, extending across the mediastinum at the second rib into the left chest, ruptured into the left pleural cavity and produced a left pneumothorax.

The factors that I mentioned as necessary for the production of a hernia are here illustrated: an enormous artificial pneumothorax in which is found 900 cc. of fluid, a mobile mediastinum, a weak spot between the first and third ribs and a completely collapsed nonexpandable lung.

LeWald and Jones have each reported bilateral pneumothorax produced by rupture through the anterior mediastinum.

A mediastinal hernia shows that the pleura, in common with other serous membranes, is capable of great stretching.

For the pneumothorax operator the discovery of a mediastinal hernia must indicate but one thing—the pneumothorax is too large. The refills must be made smaller in amount and spaced farther apart. In this way the hernia is reduced and the mediastinum is allowed to swing back to a more normal position. Once the hernia is reduced, it does not tend to recur, and the artificial pneumothorax treatments may be continued with safety.

#### CONCLUSIONS

A mobile mediastinum and a large pneumothorax seem to make the "weak spot" in the upper anterior part of the mediastinum more vulnerable to the pushing through of a hernia.

These hernias may be present when the pressure within the pneumothorax cavity is negative.

Large mediastinal hernias, or a rupture of the hernia, endanger life.

Reduction of the volume of the pneumothorax causes the hernia to disappear.

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7. Walsh, J.: *Am. Rev. Tuberc.* 9:337 (June) 1924.

tion resembling collapse. Immediate operation showed a perforation of the stomach with gangrene of the adjacent parts of the greater curvature. The possibility could not be excluded that interference with the blood supply of the stomach by its displacement in consequence of the pneumoperitoneum might have been responsible.

The question of the use of pneumoperitoneum as a differential diagnostic measure is likely to arise in a small group of cases in which the symptoms are more suggestive of hernia than of eventration, and are sufficiently severe to warrant a consideration of surgical intervention for relief. In view of the risks entailed by the production of pneumoperitoneum in such cases, an exploratory laparotomy would seem a safer procedure, and if by this means a diaphragmatic hernia is found, its repair, if feasible, may at the same time be attempted.

In cases in which hernia of the diaphragm can be excluded and the diagnosis of eventration established, fluoroscopic observation of the respiratory movements may afford evidence of value in determining the nature of the underlying disturbance. In the cases reported by Felix,<sup>17</sup> after phrenicotomy and exeresis the movements of the affected side of the diaphragm when present were constantly paradoxical. Its motion under these circumstances is entirely passive, and elevation during inspiration is due to increased intra-abdominal pressure in consequence of the descent of the unaffected half of the diaphragm. In view of these observations it may be suggested that when the respiratory motion of the eventrated diaphragm is paradoxical phrenic nerve paralysis as a cause may be suspected. Normal respiratory motion of the eventrated diaphragm implies an uninterrupted nerve supply and suggests a developmental defect in the muscular tissue as a cause of the anomaly. Correlation between the fluoroscopic observations during life and post-mortem observations are desirable before any definite conclusions regarding this matter can be made.

#### TREATMENT

Therapeutic measures will usually be limited to advice to avoid strenuous exertion, to lose weight if the patient is overweight for age and height, and other recommendations suited to the individual case. Operative procedures are not ordinarily indicated, but in cases in which the symptoms are troublesome or intolerable, surgical intervention may be considered. In Lerche's<sup>18</sup> case, with eventration and an esophago-tracheal fistula there was cough, dyspnea, inability to lie on the back or the right side without pain, and epigastric pain, distress and vomiting. Two plaits were taken in the diaphragm through an incision in the outer part of the left rectus muscle, with the addition of a cross incision in the

17. Felix, W.: *Deutsche Ztschr. f. Chir.* **171**:283, 1922.

18. Lerche, W.: *Surg. Gynec. Obst.* **34**:224 (Feb.) 1922.

are here concerned. It should be appreciated that a majority of the patients with eventration suffer from more or less troublesome symptoms, which may be ascribed to the displacement of important viscera, and before we proceed much further in the resort to phrenicotomy it would seem desirable to determine whether equally troublesome symptoms are also to be expected in this group to be operated on.

The first two cases are noteworthy because of the severity of the symptoms.



Fig. 1 (case 1).—Chest, showing the dome of the left side of the diaphragm opposite the anterior portion of the third rib; the heart and mediastinal contents are displaced to the right.

#### REPORT OF CASES

CASE 1—X. Y. Z., a physician, aged 45, who was examined Aug. 25, 1922, had been less capable than others of physical exertion all his life, but from a sense of exhaustion rather than from dyspnea. For the last six years he had been short of breath. A malposition of the left side of the diaphragm had been discovered by fluoroscopy twenty years before examination. At that time after sneezing he had had violent pain in the left side of the neck lasting for six weeks. During this period he had been troubled by pain on swallowing and laryngeal spasm which made it difficult to breathe. For the following sixteen years he had had from one to four similar attacks each year, lasting from one to two months. He then had discovered that he could stop these attacks by staying in bed. During the last four years, he had had twelve attacks of agonizing pain

observed cases of diaphragmatic hernia of extreme grade, and cases of absence of one leaf of the diaphragm. I have also found many similar cases, without symptoms, reported in the literature, almost so that I think it is necessary to consider carefully just what the relation is between eventration of the diaphragm and the symptoms of which the patient complains in a small series of cases.

DR. JOHN L. YATES, Milwaukee: I have observed the effects of induced palsy of the diaphragm over a period of approximately two years in more than a hundred patients. Temporary paralysis was induced by crushing the phrenic nerve and such of the accessory branches as transmitted motor impulses in eighty-five patients. It is impossible to study the effects of this paralysis on the patient before and after reactivation of the diaphragm. Eighteen radical operations were performed in which the nerve was extracted or resected when extraction was unwise. In none of these patients did there develop a manifestation of any intra-abdominal functional disturbance that could be attributable to the paralysis. Those who recovered function of the diaphragm so far as we could tell, did not show any particular difference before and after. Paralysis of the diaphragm reduces vital capacity, restricts external respiration and impairs competence. Dyspnea on exertion is inevitable. Blocking the phrenic nerve lessens intra-thoracic distress. It is not likely that the untoward manifestations of the patients in the cases Dr. Lord reported were due to the eventration and not provoked by the high position of the diaphragm.

DR. WILLIAM LERCHE, St. Paul: In a case of eventration of the diaphragm in which I operated some years ago, the dyspnea and the gastric symptoms were pronounced. The patient was relieved after I plicated the diaphragm. In some cases the eventration gives rise to severe symptoms; in others there are no symptoms. The question suggested by Dr. Lord is a timely one: How do we know that such symptoms may not come on in cases in which eventration has been induced by the removal of part of the phrenic nerve?

DR. LEO ELOESSER, San Francisco: There has been reason to suspect that some of these eventrations of the diaphragm are due to phrenic birth paralysis. Has Dr. Lord done a faradization of the phrenic nerves in the neck and watched the patients on the screen? This procedure may give evidence of muscular fibers or their absence on the one side of the diaphragm.

DR. WILLY MEYER, New York: The terms diaphragmatic hernia and diaphragmatic eventration are defined and understood; but here the term mediastinal hernia is used, a term accepted in the literature. Is it wise to call this bulging a hernia whereas, on the other hand, the speaker mentioned a rupture of the mediastinum to the other side? I think this nomenclature should be corrected. There is still time to do so. Modern thoracic surgery began from eighteen to twenty years ago. I would suggest a differentiation by calling it, for instance, mediastinal bulging toward the opposite side. It seems wrong to me to speak of a mediastinal hernia in these cases.

DR. EDWARD S. WELLES, Saranac Lake, N. Y.: I should like merely to add my experience to that of Dr. Yates in regard to phrenicotomy. I have performed forty-nine or fifty, and have had the same experience as he. So far I have had no evidence in any case of undue shortness of breath or any abdominal trouble after the operation. I agree entirely with Dr. Yates as to his observations.

DR. HOWARD LILIENTHAL, New York: Let me corroborate what Dr. Willy Meyer has just said in regard to the so-called hernia of the mediastinum. It is not a true hernia but a displacement of part of the mediastinum. I would also call attention to the impropriety of the descriptive title, eventration of the diaphragm. "Venter" is the Latin for belly. That part of the cavity that is under-

The patient was well developed and slightly obese. There was slight cyanosis of the lips. The chest was symmetrical; the circumference of the left half was 41 cm., of the right half, 42 cm. With the patient on her back, the inspiratory excursion of the left side was greater than that of the right. exaggerated motion was noticeable throughout the left side of the chest in the left clavicle to the costal margin. There was an exaggeration of the inspiratory widening of the left side of the subcostal angle and the costal margin with inspiratory retraction of the epigastrium. On percussion the left side was dull



Fig. 2 (case 2).—Chest, showing the dome of the left side of the diaphragm opposite the anterior portion of the third rib; the heart and the mediastinal shadow are displaced to the right.

below the third rib in front and the middle third of the scapula behind. The note was dull and tympanitic over and below the left breast. There was no tympany in the left axilla or back. The upper border of dullness behind was highest in the region of the scapula, and curved slightly downward from this point toward the spine and the axillary region. The left paravertebral region was less dull than other parts of the left side of the back. There was no Grocco's triangle of dullness and no spinal dullness. The inspiratory excursion by percussion was 3 cm. in the right and 1 cm. in the left side of the back. The diaphragm shadow (Litten's phenomenon) was absent on both sides.



# CONGENITAL ABSENCE OF LEFT HALF OF THE DIAPHRAGM

DIFFERENTIAL DIAGNOSIS FROM EVENTRATION, HERNIA AND THORACIC  
STOMACH, WITH A REPORT OF THREE CASES

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The first case of congenital absence of the left half of the diaphragm, although reported by Harris and Clayton-Greene<sup>1</sup> in 1912, appears to have been overlooked since that time (figs. 1 and 2). Without doubt many cases recorded as hernia of the diaphragm have really been cases of congenital absence of the left half of the diaphragm. Even roentgenologists have not recognized the true nature of these cases. Surgical operations have been undertaken under an erroneous diagnosis of hernia, and attempts to overcome the defect have failed.

Attention is called to the fact that the diaphragm is not essential to life. One should never lose sight of the fact that complete absence of the diaphragm is normal in all animals below mammals.<sup>2</sup> It is of interest that a bird such as the ostrich, which is noted for its strength and endurance, has no diaphragm. In one of the cases recorded here, it is to be noted that the patient was able to enter into athletic contests and, among other events, was a successful entrant in a 5 mile relay race.

On roentgen-ray examination the appearance may closely simulate eventration of the diaphragm (fig. 3). In cases of thoracic stomach (fig. 4), a misinterpretation is also possible. The differential diagnosis can be made only by the aid of direct lateral roentgenologic examination. In this position in the normal person, both the right and left leaves of the diaphragm can be seen throughout their entire extent; hence, the absence of one leaf or a portion of it can be readily determined. In eventration of the diaphragm, no matter how thin or how high the outline of the diaphragm, it can be distinguished.

The exact recognition of congenital absence of the left half of the diaphragm is extremely important from the surgical standpoint, as the condition does not lend itself readily to surgical repair. In a case reported by Clayton-Greene, total absence of the left half of the dia-

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1. Harris, W., and Clayton-Greene, W.: Congenital Absence of the Left Half of the Diaphragm, Simulating Pneumothorax, *Proc. Royal Soc. Med.*, 1911-1912, p. 153.

2. Colton, B. P.: *Zoology*, Boston, D. C. Heath & Co., 1909, p. 283.

note was dull and tympanitic throughout the left front of the chest and axilla as far as the postaxillary line. Posteriorly, the upper limit of dullness was over the scapula and curved thence downward toward the spine and postero-axillary region. The left paravertebral region was less dull than other parts of the left side of the back. There was no Grocco's triangle and no spinal dullness. The inspiratory excursion was 3 cm. on the right and 1 cm. on the left. The diaphragm shadow was 3 cm. in amplitude in the right axilla and was not seen on the left side. On auscultation, the breath sounds were present but diminished throughout the left side. No bronchial breathing was heard. Gurgling sounds



Fig. 3 (case 3).—Chest, showing the dome of the left side of the diaphragm opposite the anterior portion of the first rib.

resembling those due to intestinal peristalsis were heard below the left clavicle, throughout the left axilla and as high as the spine of the left scapula behind. The voice and whisper were normal throughout the left side. No egophony, succussion splash or râles were heard. Tactile fremitus was diminished but not absent throughout the left side below the second rib in front and the spine of the scapula behind.

The cardiac impulse was felt in the fifth left interspace at the nipple line. The heart sounds were regular and of good quality. No murmurs were heard. The rate was 72.

phragm was found following an operation for supposed diaphragmatic hernia. The operator found it impossible to bridge the defect in the diaphragm and accomplished nothing by the operative procedure. Had the case been carefully studied roentgenologically, the correct diagnosis could have been arrived at and the dangerous operative procedure avoided. A report of this case follows:

A woman, aged 31, 5 feet, 10 inches tall, strongly built and heavy, had been married five years, and had two children. Five years previously, she had



Fig. 3.—Eventration of the diaphragm on the left side: the heart is displaced to the right, simulating dextrocardia; the stomach, however, is on the left side. Autopsy showed absence of all muscle tissue in the left leaf of the diaphragm.

fallen downstairs and had broken two ribs on the left side. Four years later, she again jarred the left side badly when motoring. On physical examination, there was dulness at the base of the left lung. Roentgen-ray examination of the chest showed a sickle-shaped shadow at the left base, with a brilliant area above and internal to this shadow. A diagnosis was made of localized pleural effusion with localized pneumothorax and partial collapse of the left lung. Later, a diagnosis of hernia of the diaphragm following rupture due to the fall was made, and an operation was undertaken. A total absence of the left side of the diaphragm was found.

clinical means alone, and it is desirable that their value be further tested in cases that subsequently come to operation or necropsy, as by such means alone can the diagnosis be established beyond doubt.

Other physical signs, dulness, dull tympany, diminished or absent breathing, diminished or absent voice, whisper and tactile fremitus, are found with a variety of intrathoracic conditions (pulmonary cysts, tumors, atelectatic areas from bronchostenosis and accumulation of fluid or solid material in the pleural sac), as well as with diaphragmatic eventration and hernia. When in addition to such signs it is noted that the dulness changes with the intake of food or fluid into the stomach, eventration or hernia may be suspected. The presence of sounds due to intestinal peristalsis over the affected side has been noted in a number of the reported cases. When such sounds are abnormal in their loudness or extent, they may have diagnostic significance and serve to suggest diaphragmatic eventration or hernia; but in the interpretation of peristaltic sounds over the thorax as an indication of eventration of the diaphragm or hernia, it must be remembered that such sounds are normally present over the lower parts of the chest, and may be heard on the left as high as the third rib in front and the lower third of the scapula behind, and at a somewhat lower level on the right. They are much louder on the left than on the right side. I have compared the intensity and extent of these sounds in the three cases reported here with similar sounds in normal chests, and doubt that they have any special diagnostic value.

Of special methods of examination, determination of changes in intragastric pressure with other evidence enabled Hildebrand and Hess<sup>9</sup> to make the differential diagnosis between eventration and hernia in the much discussed case of Schneider, who was examined in many German clinics from the age of 12 until his death at 46. A stomach tube was connected with a manometer, the lever of which indicated on a revolving drum the changes in intragastric pressure. A tracing of the respiratory movements was taken at the same time. The curves with deep breathing were identical with those obtained<sup>10</sup> from a normally placed stomach, i. e., a fall of pressure at the beginning both of inspiration and of expiration and a subsequent increase in pressure to the height of both phases of respiration. They concluded that if the stomach showed normal pressure curves, especially a positive pressure at the height of inspiration, it must lie under the diaphragm. At necropsy<sup>11</sup> their diagnosis of left-sided eventration of the diaphragm was confirmed.

This method, of value in this case, deserves further trial. It was not used in the cases reported here. There is one other report of its use

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9. Hildebrand and Hess: *München. med. Wchnschr.* **16**, 1905.

10. Schlippe: *Deutsches Arch. f. klin. Med.* **76**, 1903.

11. Bergmann: *Ergebn. d. inn. Med. u. Kinderh.* **12**:327, 1913.

over half of the small intestine, the cecum, a portion of the large intestine, practically all of the distended rumen, the spleen and part of the pancreas to pass into the left pleural cavity. The left lung, which was totally collapsed, was only about half normal size. The mediastinum, esophagus, aorta and apex of the heart were markedly displaced toward the right side.

Hume<sup>5</sup> gives an excellent description of the development of the diaphragm:

The diaphragm arises by modification of the septum transversum of the early embryo. This septum is mainly a mesoblastic vehicle for the ducts of Cuvier from the body wall to the heart. It occupies an oblique plane, sloping downwards and forwards from the cervical region, immediately dorsal to the heart. From this position it makes a gradual descent, reaching its final level about the third week of intra-uterine life.

During the third week it has a posterolateral opening on either side, the hiatus pleuroperitonealis, through which the lung buds pass upward, as the septum transversum descends; the pleural cavity thus being an extruded portion of the coelom. As the septum transversum descends, mesoblastic cells in the lower dorsal region, representing the cephalic end of the primitive mesentery, proliferate, and, bridging across the opening, establish a connection with the septum transversum.

The diaphragm is thus constituted of a ventral portion derived from the septum transversum, and a dorsal portion derived from the primitive mesentery. In the primitive mesentery, near its free border, is placed the developing esophagus and stomach.

In the fourth week the hiatus pleuroperitonealis is closed by a double fold of pleura and peritoneum. Muscle fibers are now present in the septum, but not in the membrane closing the hiatus. This can be seen macroscopically from the fifth to the twelfth week as a transparent triangular area situated between the costal and spinal muscle origins.

The thinnest portion of the rest of the diaphragmatic sheet is the central area of each dome. The right dome is completely filled by the liver, while the left contains a small portion of liver, the stomach and coils of intestine of the proximal and distal loops of the midgut, which are undergoing rotation about the axis of the vitelline artery. The grouping of intestine in this region is due to the fact that this is the most roomy part of the abdominal cavity, the anteroposterior diameter of the lower abdomen being much less and the pelvis merely a potential space.

. . . Congenital hernia occurs through the left dome most commonly . . . and is due to some primary congenital ectopia of viscera, occurring at the time of formation of the diaphragm, and sometimes associated with incomplete rotation of the intestine (fig. 5).

In describing congenital diaphragmatic hernia, Hume states:

Complete absence of the left half of the diaphragm is not infrequently found in fetal cases. The whole diaphragm to the left of the esophageal opening and the left crus is absent. Parietal pleura and peritoneum form a continuous

5. Hume, J. B.: Congenital Diaphragmatic Hernia, *Brit. J. Surg.* 10:207-215 (July) 1922.

conceive of this with the left half of the diaphragm the seat of aplasia. Defective development of the diaphragm has been established at necropsy in certain cases but is not necessarily implied by the term eventration, and in the case reported by Duval and Quenu,<sup>14</sup> the diaphragm at operation had a normal appearance and thickness. Owing to the much smaller volume of that part of the thoracic cavity above the affected diaphragm compared with that of the opposite side, a relatively greater negative pressure may result from the descent of the diaphragm and contraction of the intercostal muscles on the affected side. In consequence of such relatively greater negative pressure on the affected side, the heart and mediastinum, if free from adhesions, may be expected to move toward that side, and the observation does not seem inconsistent with mechanical conditions which may obtain with eventration of the diaphragm.

Roentgen-ray examination after the production of pneumoperitoneum may be regarded as the most certain means of differentiating eventration from diaphragmatic hernia. It is a question, however, whether its dangers justify its use. Schlecht and Wels<sup>15</sup> were deterred in a doubtful case of eventration of the diaphragm from the employment of this method on account of the possible dangers until the diagnosis had been established by exploratory operation. Roentgen-ray examination then enabled them to identify the arched line above the oxygen filled abdominal cavity as that of the diaphragm. After the abdomen had been insufflated with 1,500 cc. of oxygen, the patient complained of pain, which was ascribed to the stretching of adhesions between the liver and the diaphragm. In the presence of diaphragmatic hernia, pneumoperitoneum may entail some risk. The absence of a sac in a large majority of the cases of diaphragmatic hernia makes it likely that the introduction of gas into the peritoneal cavity will cause pneumothorax, on account of imperfect closure of the defect in the diaphragm by the hernia. Schlecht and Wels<sup>16</sup> report the use of this method also in a case of congenital diaphragmatic hernia, and were thus able without difficulty to recognize the nature of the disturbance. The production of pneumothorax by the introduction of the gas into the abdomen indicated the presence of an open communication between the abdomen and the thorax. The spleen, stomach and other shadows due to the stomach or large intestine were seen above the diaphragm. Three weeks after entrance to the clinic, the patient had a severe attack of pain, and was in a condi-

14. Duval and Quenu: *Bull. et mém. Soc. nat. de chir.* 50:178, 1924.

15. Schlecht and Wels: *Fortschr. a. d. Geb. d. Röntgenstrahlen.* 27:244, 1920.

16. Schlecht and Wels: *Fortschr. a. d. Geb. d. Röntgenstrahlen.* 27:544, 1920.

CASE 1.—J. M., a Scotchman, aged 31, referred by Dr. W. A. Downes, had had distress in the intestinal tract, with gas, which had started as a chronic condition but had become acute. During his high school period, in spite of a diagnosis of dextrocardia, he had engaged in the usual amount of athletics, such as running and football. He had had several roentgen-ray examinations for disturbance around the heart, but the condition of the diaphragm was not recognized until it was observed by another roentenologist; he, however, diagnosed the condition as eventration.

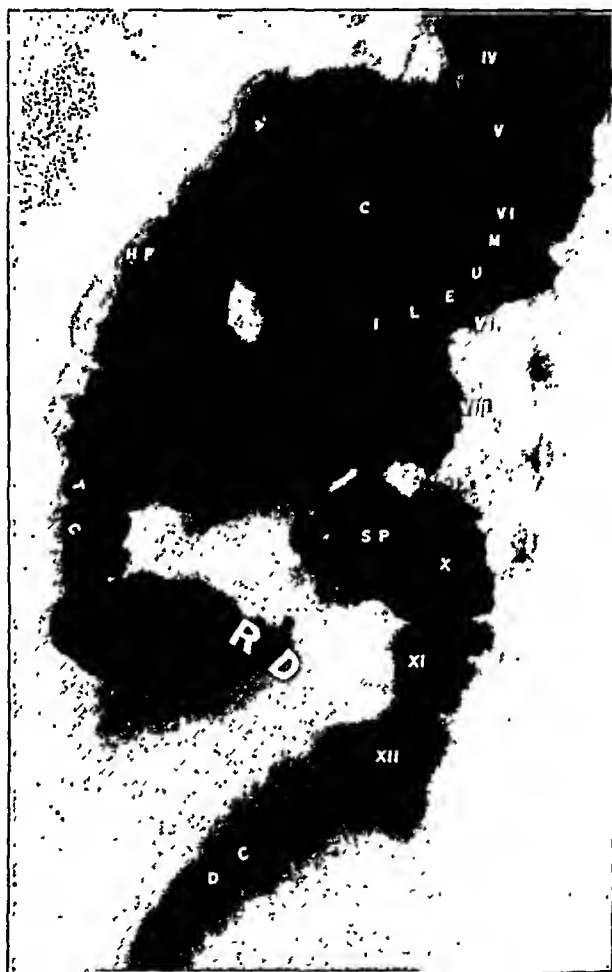


Fig. 6 (case 1).—Lateral view of absence of left half of diaphragm in a man, aged 31: *R. D.*, position of right side of diaphragm. It should be noted that no shadow of the left side of the diaphragm can be made out, as it is absent.

Roentgen-ray examination disclosed a deficiency in the left side of the diaphragm with the entire ileum, greater portion of the jejunum and the first half of the colon in the chest cavity (figs. 6 and 7). This condition was apparently associated with nonrotation of the colon. The stomach was ptosed, occupying an extremely low position in the abdomen. In spite of the low position of the stomach and the abnormal position of the intestine, the stomach emptied in five hours, at which time the meal was entirely in the left side of the chest cavity. There was no evidence of a limiting membrane or sac about the colon. Examination of the chest showed the right border of the heart

upper end of the rectus muscle. Seven months later there were "hardly any cough," no digestive symptoms and ability to lie on the back and right side with perfect comfort. In Duval and Quenu's<sup>14</sup> case, surgery was advised on account of almost daily paroxysms of severe pain in the left hypochondrium, and was preceded by the production of artificial pneumothorax to avoid the danger of sudden collapse of the lung during operation. A thoraco-abdominal incision was made, and three plaits were taken in the diaphragm. For two months after operation there were no paroxysms resembling those the patient had had before.

I am indebted to Dr. George W. Holmes for his cooperation and assistance in the roentgen-ray examination of these patients.

#### ABSTRACT OF DISCUSSION ON PAPERS OF DRS. PACKARD AND LORD

DR. J. J. SINGER, St. Louis: This question of the use of pneumothorax and its availability to surgeons is resulting in the latter attaching internists to their staffs, so that what occurs in pneumothorax cases is of vital importance to internists, especially this particular point, hernia of the mediastinum. I have been somewhat in doubt as to whether it is really a hernia, whether the mediastinum is actually torn through and the pleura extends into the opposite cavity, or whether the mediastinum, as a whole, is pushed into the opposite lung space. One of the greatest surprises to surgeons performing pneumothorax is the observation through the fluoroscope of a tremendous air pocket when 200 or 300 cc. of air is forced into the pleural space. How did it get there? Evidently there was spontaneous rupture of the lung during the performance of artificial pneumothorax. That happens much oftener than is suspected. Frequently, the spontaneous rupture or the amount of air that enters the pleural cavity is small because of adhesions of the pleura at various parts, so that it is always best to look with a fluoroscope. One should not stop with the manometer readings. Manometer readings are misleading. A negative pressure may be recorded and yet the pleural space be full of air. That is because the collapsed lung is so much collapsed that it is almost theoretically a part of the mediastinum tissue; hence, the opposite pleural pressure is being registered. Graham and Bell's work showed that when pressure is taken that way, the pressure of the opposite cavity is being taken. I feel that a pneumothorax performed in the home or without the use of the fluoroscope is a mistake.

DR. CARL A. HEDBLOM, Chicago: Dr. Lord has raised an interesting question in relation to phrenicotomy. His observations show the importance of being conservative in recommending this operation, which in itself is so simple and seemingly harmless that we may be tempted to use it in cases in which it is not properly indicated. On the other hand, I think that the question as to indications for it is one of relative value. In the treatment of tuberculosis, it must not be forgotten that one is dealing with a serious disease which if not arrested will eventually cost the patient his life. And an operation that may prove helpful in securing arrest of the tuberculous process would seem justified even at the expense of a certain amount of functional derangement. In case phrenicotomy is preceded or followed by thoracoplasty, it would also seem probable that the collapsed state of the lower thorax might well tend to counteract any tendency to functional derangement from a high nonfunctioning diaphragm. I have also



to be about 4.5 cm. to the right of the median line. The apex was obscured by an area of density which was continuous with and about equal in density to that of the abdomen. The left side of the diaphragm could not be seen. The trachea was slightly more to the right of the midline than is usual. Both lungs showed a normal appearance, with an unusual amount of pulmonary area on the right side.

Six years later, this patient was alive and expressed himself as being "marvelously well." He also stated that he believed that he had less of the ordinary distress and stomach trouble than the average normal person.

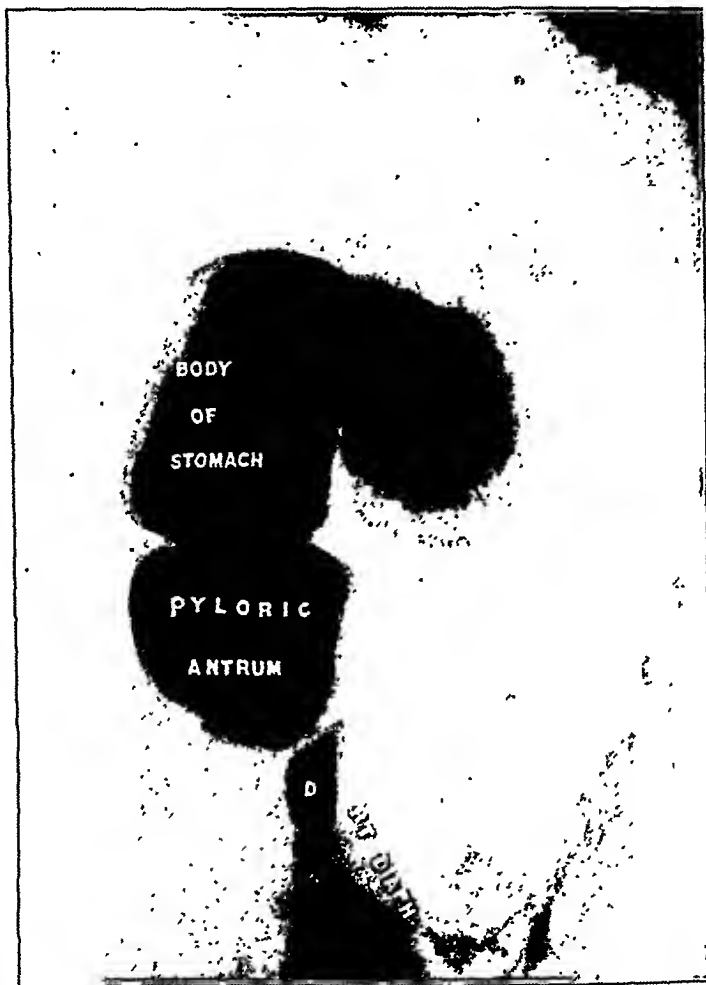


Fig. 8 (case 2).—Lateral view of absence of left half of diaphragm in a woman, aged 62; the right side of the diaphragm is visible, but the left side is absent; the stomach shows a remarkable appearance, being inverted. Note similarity to figs. 2 and 5.

CASE 2.—A. R., a woman, aged 62, referred by Dr. Mills Sturtevant, complained mainly of coughing a great deal and of pain through the shoulders. For about six years she had had discomfort and pain in the midepigastriic region after eating. The patient had had a roentgen-ray examination prior to the time I saw her, after which she had been told that she had a "double stomach" which would require surgical treatment.

Roentgen-ray examination showed the stomach to be inverted (fig. 8) and to be situated in the left side of the chest. The small intestine was entirely in the abdomen. The cecum was extremely low in position, but the splenic flexure of

neath the diaphragm is the belly. It is the elevation of the belly and not the eventration of the diaphragm. I suggested that it be called elevation of the diaphragm and not eventration. Another misnomer is worth mentioning. If you will refer to a recent number of the *Journal of the American Medical Association*, you will find a letter of mine on the use of the word "benign" in contradistinction to "malignant." There is no such thing as a benign tumor. It may be nonmalignant or innocent, but no tumor is benign.

DR. LEON T. LEWALD, New York: Dr. Lord asked for an opinion as to the value or use of artificial pneumoperitoneum in the differential diagnosis of lesions about the diaphragm. I am opposed to it, as not being necessary and somewhat dangerous. It is always possible to show the entire diaphragm roentgenographically if one makes a careful lateral exposure. One can show both sides of the diaphragm in a normal person. It is not necessary to inject air into the peritoneal cavity to make a differential diagnosis between eventration and diaphragmatic hernia, or congenital absence of the left side of the diaphragm.

DR. FREDERICK T. LORD, Boston: Dr. Lilienthal's criticism regarding the term eventration is well made. The term is a misnomer. The only justification for it is common usage. Regarding the possible dangers to the patient of a phrenicotomy and exeresis, I do not believe that one can judge the matter so early in experience with this procedure. Persons with eventration apparently may go for a long period without symptoms and then develop symptoms, and the question as to the deleterious effect of this procedure cannot be answered without the lapse of more time. The suggestion was made that a determination of the nature of the disturbance may be made by electrical stimulation of the phrenic nerve. Lack of response might be taken to indicate a disturbance in the nerve. It might also be taken to indicate no response in muscle that is inefficient. I think there is some doubt as to the interpretation of the results, and there has been no experimentation with this procedure.

DR. E. N. PACKARD, Saranac Lake, N. Y.: I think Dr. Lilienthal's criticism of the word "hernia" is justified but it is a term that has been used generally in the German and French literature to describe the culdesac, or pouch, which bulges into the sound side across the mediastinum. The "hernia" is covered by the parietal pleura of the pneumothorax and by the parietal and visceral pleura of the sound side.

identical with that in case 1. No fluoroscopic or chest examination was made. Hence the fact was not determined that the opaque substance was all in the chest cavity at this time, as was observed in case 1.

A brief summary of the case as reported by Dr. Vogel<sup>6</sup> is:

The patient complained of abdominal pain and showed symptoms referable to stenosis of the large intestine. Necropsy revealed a large defect in the left side of the diaphragm. The left border of the heart was 2.5 cm. to the right of the midline; the right border was 11.5 cm. to the right of the midline. A considerable portion of the colon, including the cecum and appendix, together with the stomach and spleen were in the chest cavity (fig. 10). The opening in the diaphragm measured 6 inches (15.2 cm.) in diameter. There was no hernial sac. The sigmoid flexure showed evidence of diverticulitis, with marked inflammatory reaction and stenosis.

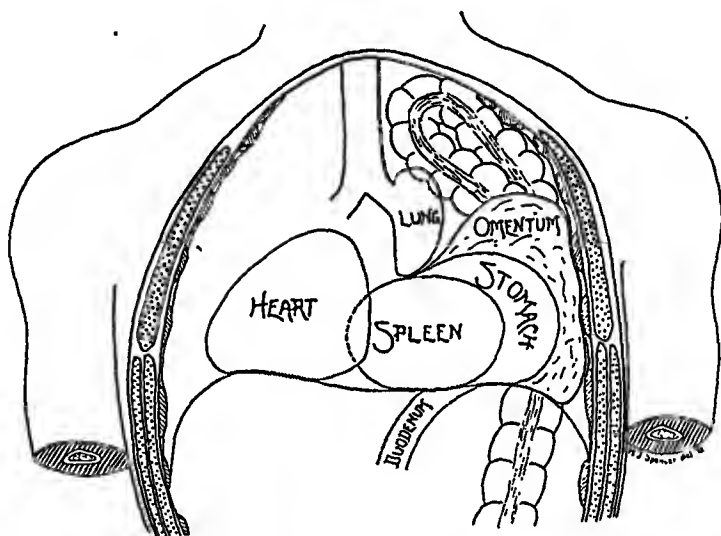


Fig. 10 (case 3).—Appearance at autopsy in a case of a large defect, 6 inches (15.2 cm.) in diameter, in the diaphragm. The contents of the chest were similar to those in a case of complete absence of the left side of the diaphragm.

Vogel reports the case as one of "false congenital diaphragmatic hernia" in view of the absence of a sac. In view of the large size of the defect in the diaphragm, this case might well be classified with the cases of congenital absence of the left half of the diaphragm. In this respect it closely resembles cases 1 and 2. It is also interesting to note that case 1 also occurred in a Scotchman and case 2 was complicated by multiple diverticula of the colon, as was also case 1.

The necessity for making a thorough fluoroscopic and roentgenographic examination in all cases of obscure symptoms referable to the abdomen or chest is illustrated by this case in which a limited roentgen-ray examination was made at the special request of the attending surgeon.

6. Vogel, Karl: Diaphragmatic Hernia, with Report of a Case, *Am. J. M. Sc.* 145:206 (Feb.) 1913.

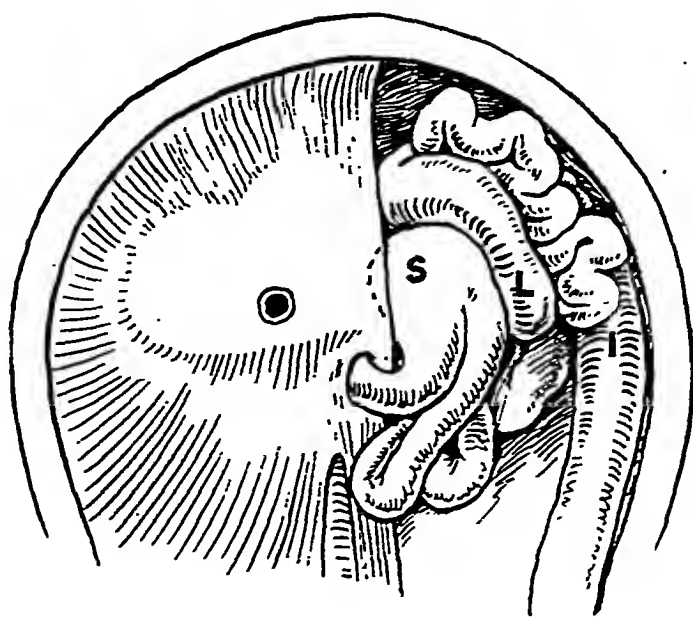


Fig. 1.—Abdominal aspect, showing absence of left half of diaphragm diagrammatic. (From J. B. Hume, London; specimen preserved in the museum of St. Bartholemew's Hospital, London.)

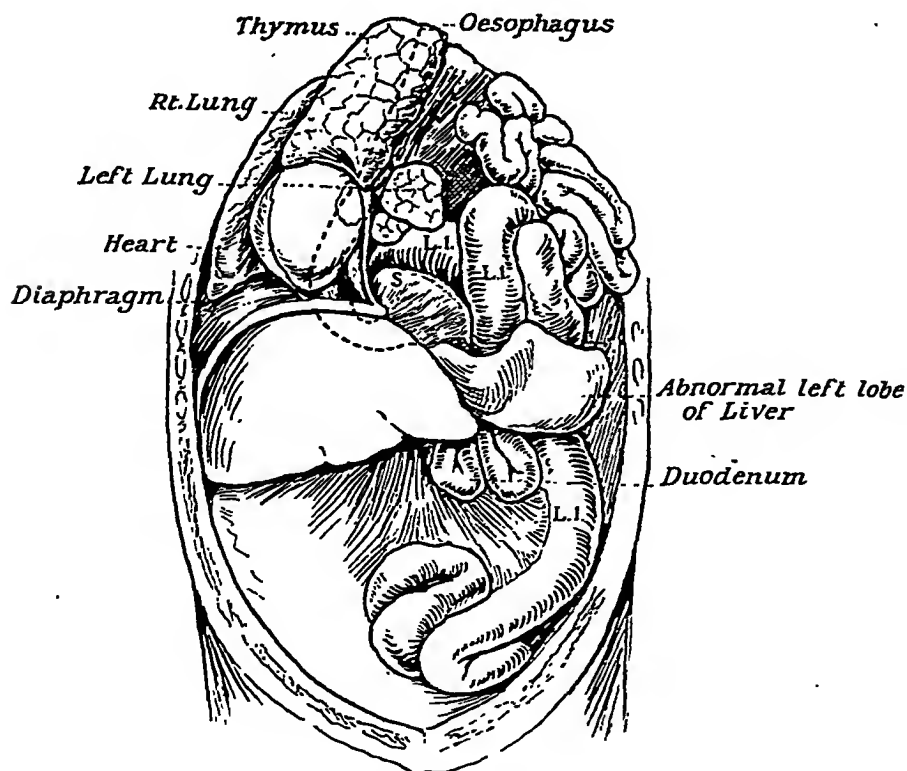


Fig. 2.—Absence of the left half of the diaphragm in the same case as figure 1, showing the course of the esophagus by the dotted lines: S, stomach; L. I., large intestine. (From J. B. Hume, London.)

nation. In the second case, that of a woman, aged 69 years, the correct diagnosis of thoracic eventration was made on roentgen-ray examination.<sup>10</sup>

In differentiating congenital absence of the left half of the diaphragm from a true diaphragmatic hernia, roentgen-ray examination is believed to be reliable, but should always include examination in the lateral position, as in this position the diaphragm can be made out if present. The latter fact is particularly true in hernia through the esophageal opening, a condition that is being recognized with increasing frequency on careful roentgen-ray examination of the digestive tract.

### CONCLUSIONS

Congenital absence of the left side of the diaphragm is a rare condition but should never be confused with true diaphragmatic hernia, eventration of the diaphragm, or thoracic stomach.

The question of operability depends on the size of the congenital defect. In cases of complete absence of the left half of the diaphragm, it might be necessary in a particular case to operate for some complication, such as acute or chronic appendicitis, in which case the exact location of the appendix should be determined by means of the roentgen ray, and a suitable incision made at the nearest point. After undertaking the necessary surgical procedure, no attempt should be made to remedy the defect.

Congenital absence of the diaphragm is not incompatible with longevity.

In cases of traumatism to the abdomen or chest, congenital absence of the left side of the diaphragm should always be borne in mind and recognized in contradistinction to a supposed diaphragmatic hernia.

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10. Lewald, L. T.: Thoracic Stomach, Differentiation from Eventration and Hernia of the Diaphragm, *Radiology* 3:91 (Aug.) 1924.

Keith,<sup>3</sup> in his article on diaphragmatic hernia, records three cases of congenital absence of one side of the diaphragm in the fetal stage and one case similar to Clayton-Greene's case. The ability of a person to survive with diaphragmatic hernia or congenital absence of the left side of the diaphragm is proved by one of Keith's patients who lived to be over 70 years of age, and one of mine who is 62.

Meyer<sup>4</sup> reports a case of congenital absence of the left half of the diaphragm in a new-born lamb which had survived birth but a few



Fig. 4.—Thoracic stomach, showing that the stomach has been completely developed above the intact diaphragm. The duodenum passes through the opening in the diaphragm which would normally be the esophageal orifice.

moments. When the abdomen was opened, the most striking feature was the absence of the larger portion of the intestines, which made the abdomen seem comparatively empty. Further examination showed the greater portion of the left half of the diaphragm to be absent, allowing

3. Keith: *Brit. M. J.* 2:1297, 1910.

4. Meyer, A. W.: *Spolia Anatomica*, *J. Anat. & Physiol.* 9, 1914.

receiving tambours could be fastened to the horizontal bar by a chain of exactly the same length on the two sides. From the upper hook of the tambours other chains passing across the front of the chest could be fastened to hooks of equal height on the opposite upright. With such an apparatus it was possible to keep the tension on the two tambours exactly the same. The movements of the two sides were recorded simultaneously by recording tambours on the kymograph. Thus, a record could be kept and the observations of clinical examination confirmed. After the observations both by physical examination and tambour readings had been completed, the animals were observed under the

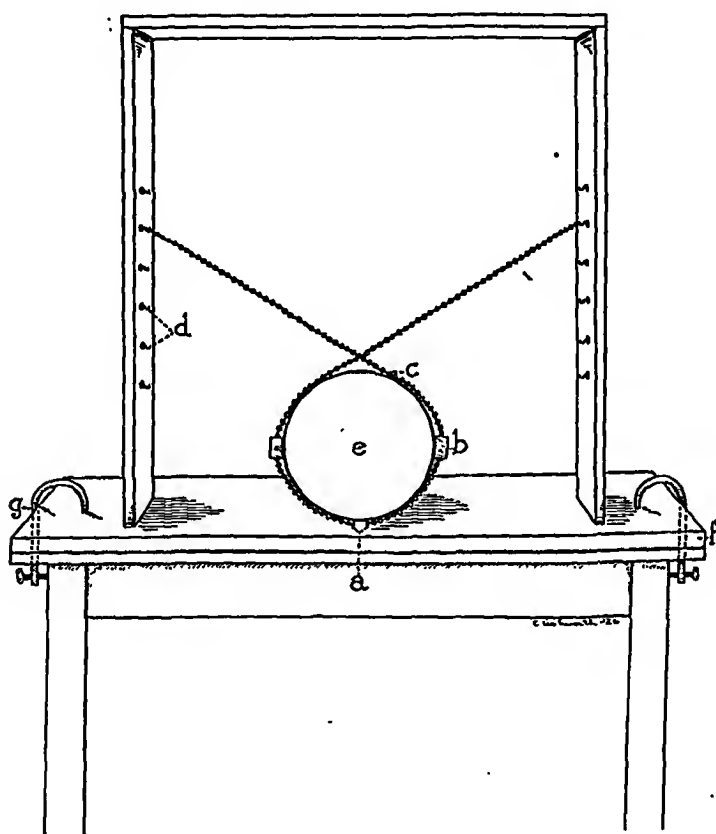


Fig. 1.—Dog in apparatus: *a*, central hooks for attachment of side chains; *b*, tambour; *c*, side chain attached to opposite upright; *d*, hooks equally spaced, measured from bottom upward; *e*, dog on back; *f*, base board; *g*, clamps to fasten to table.

fluoroscope and roentgenograms made of the chest. To preserve uniformity in the latter, roentgenograms were always made at the height of inspiration. This was easy of accomplishment because it was necessary only to hold the nose of the dog when the lung was expanded. There was always sufficient time to take a satisfactory roentgenogram. After all records had been completed, the animals were killed and studied at necropsy to determine whether or not pathologic changes were apparent (fig. 1).

sheet. Abnormal lobes or semidetached portions of the liver are frequently found, and the greater part of the intestine, in a partially rotated condition, lies in the chest. Such a condition is almost always compatible with life, though it is recorded that one boy lived to the age of 10 years.

In view of the apparent lack of recognition of congenital absence of the left half of the diaphragm, owing to confusion with diaphragmatic hernia and eventration of the diaphragm, the following three cases are



Fig. 5.—Hernia through a large defect in the left dome of the diaphragm: The inverted position of the stomach (*S*) in the chest cavity should be noted; the cecum, transverse colon and splenic flexure (*L. I.*) also are in the chest cavity. An erroneous roentgen-ray diagnosis was made of "complete pneumothorax, left side, the left diaphragm considerably higher than the right." (From J. B. Hume, London; specimen preserved in the museum of St. Bartholomew's Hospital, London.)

recorded, together with the necropsy reports in a fourth case. As far as known, cases 1 and 2 are the first two cases in which the roentgen-ray diagnosis of congenital absence of the left half of the diaphragm has been made.



anesthesia and standard surgical technic. The phrenic nerve was isolated and carefully traced so that all tributaries might be identified. It was then drawn upward and cut off or evulsed, and the wound closed. Observations were made the following day. In every instance, physical and fluoroscopic examinations and tambour records were made.

Inspection of the chest invariably failed to show the slightest departure from normal. After the wounds had healed and the scars of operation were no longer apparent, several animals were brought to the examining room. Some were normal; in others the right phrenic nerve had been cut, in others the left phrenic nerve, and in one both phrenic



Fig. 2.—Right phrenic neurectomy; right phrenic nerve cut, showing elevation of the right side of the hemidiaphragm.

nerves had been cut, yet by observation it was impossible to distinguish the normal animals from those subjected to operation, and equally so to determine among the latter group which side had been operated on.

By percussion it was possible to locate the side of the severed nerve because of the higher area of dulness on that side, the lessened excursion of resonance during respiration and the slight departure of the heart from its normal position. It was impossible to determine the side of operation by means of the kymograph record. In each instance the tambour



Fig. 7 (case 1).—Absence of left half of diaphragm in a man, aged 31: It should be noted that there is no shadow of the diaphragm on the left side; the terminal ileum, the cecum, appendix, ascending and transverse colon and the hepatic and splenic flexures are all in the chest cavity on the left. In some respects, this may be regarded as nonrotation of the colon associated with absence of the left half of the diaphragm; the heart is displaced to the right, but is not transposed.

diaphragm on the unaffected side moves normally through its customary excursion.

In this way, respiratory movements are shortened in one direction because the length of the thoracic cage is decreased. In no other direction are changes apparent. Not only the unaffected half of the diaphragm moves through its normal cycle but the thoracic wall and the costal margins act independently and move without restriction through their normal cycles and in their normal directions.

Without the fluoroscope, the examiner is unable to decide which is the affected side, whether he employs inspection alone or inspection combined with palpation. Percussion of the lower borders of the lungs and the position of the heart give some clue to the affected side, but little

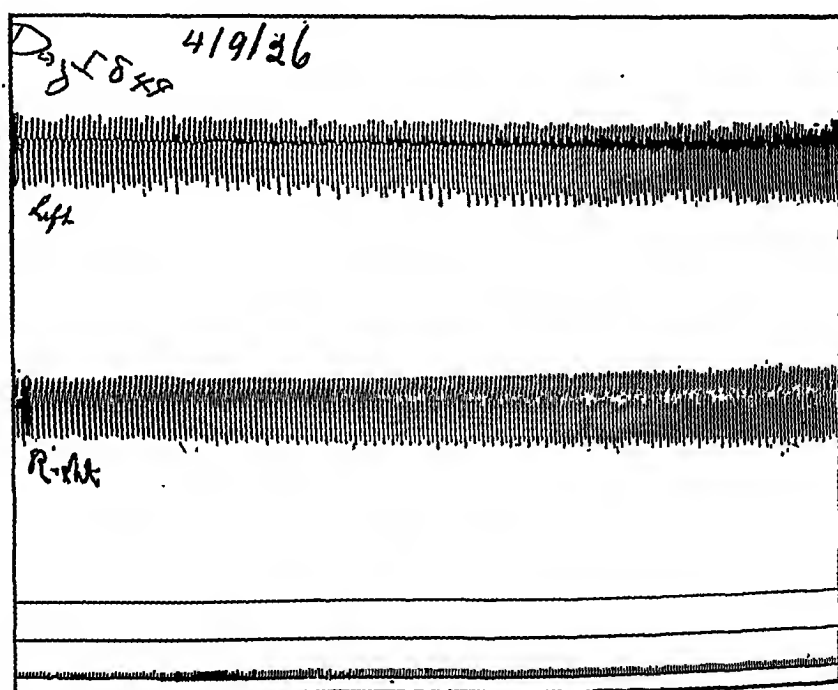


Fig. 4.—Right phrenic nerve severed; reading made with animal anesthetized with ether; movements of chest wall equal on two sides; normal outward movements of costal arches during inspiration. Paralysis of the right side of the diaphragm was seen on fluoroscopic examination; the right half of the diaphragm was found atrophied at necropsy; intrapleural pressure was equal on the two sides.

help is obtained by auscultation; the breath sounds are apparently unaltered and no evidence of congestion can be found. In examinations of animals several weeks after phrenic neurectomy, it was impossible to determine with exactness the side that had been operated on when only physical examination and tambour readings were available.

Dog 2 afforded a specific illustration of the common observations. Inspection, palpation and auscultation gave no clue to the side of operation, and the heart seemed to be in the middle of the chest. The animal

the colon was in contact with the stomach in the left of the chest. There also was evidence of multiple diverticula of the pelvic colon (fig. 9). The lungs showed evidence of chronic interstitial pneumonitis of nontuberculous nature, associated with chronic bronchitis, but without the presence of bronchiectasis. It is believed that the patient's cough was due to the condition of the lungs, and that the condition of the diaphragm was purely incidental.

CASE 3.—G. P., a man, aged 37, referred to Willard Parker Hospital from the occupational clinic of the Board of Health of New York City, had a roentgenographic appearance similar to that observed in cases 1 and 2 from a



were being made. In each case, physical examination failed to disclose differences in breathing.

The readings taken on dog 5 were particularly interesting because of the perfect rhythm of respiration and the equality in depth of successive inspirations and expirations. The manometer levels were always identical, rising and falling in unison.



Fig. 5.—Two water manometers mounted side by side, each connected with needles of equal caliber. The needles were inserted at the same level in the axillary line and readings were taken in both inspiration and expiration.

When readings were taken on dog 3, in which the right side of the hemidiaphragm had been paralyzed, and had been seen under fluoroscopic examination to remain high in the thorax, the readings showed

No discretion was allowed the roentgenologist to make a complete examination, which prevented making a correct antemortem diagnosis in this case.

Vogel himself, in commenting on false congenital diaphragmatic hernia, called attention to a case by Klebs<sup>7</sup> in which the diaphragm was totally absent, yet the child lived until he was 6 years of age.

#### DIFFERENTIAL DIAGNOSIS

Differential diagnosis between eventration of the diaphragm and congenital absence of the left half of the diaphragm can be made roentgenologically, especially in lateral exposures. In eventration, however high the diaphragm may be, its outline can be seen. In congenital absence of the left side of the diaphragm, while the upper border of the stomach or portion of the colon may have a domelike appearance at times, repeated examination will show a change in the contour of these shadows.

Two cases of thoracic stomach have been examined by me and one case was confirmed by operation. Thoracic stomach is a term used particularly by Bailey<sup>8</sup> to indicate the presence of the stomach in the chest cavity without any evidence of an abnormal opening in the diaphragm. In both of these cases it was a simple matter to demonstrate the entire intact diaphragm on each side of the chest, and at no time could any portion of the stomach be found below the diaphragm. Furthermore, no other abdominal structure was found above the diaphragm at any time. These observations would serve to distinguish a case of thoracic stomach from either a true diaphragmatic hernia or a congenital absence of a portion of the diaphragm. This condition has also been described as diaphragmatic hernia of the stomach with short esophagus,<sup>9</sup> and other observers have called attention to the fact that this type of anomaly of the stomach is such that it is impossible to bring the stomach down into the abdominal cavity. However, it may at times be necessary to relieve some condition of the stomach itself, in which case the operative procedure would be undertaken through the chest cavity; or, as in a patient operated on by Downes, a gastro-enterostomy may be performed through what would ordinarily represent the esophageal orifice in the diaphragm. This case in a boy, aged 7 years, is the first one recorded in which a correct diagnosis of thoracic stomach was made by roentgen-ray exami-

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7. Klebs, reported by Eppinger: *Allgemeine und specielle Pathologie des Zwerchfells*, Supplemente H. Nothnagel's *Specielle Pathologie und Therapie*, Vienna, 1911.

8. Bailey, P.: *Anat. Rec.* **17**:107-109 (Oct. 20) 1923.

9. Fineman, S., and Conner, H. M.: Right Diaphragmatic Hernia of the Short Esophagus Type, *Am. J. M. Sc.* **167**:672 (May) 1924.

volume of the lung is decreased by lessening of one dimension only. It remains to be seen whether or not vital capacity is markedly impaired or whether abnormal or pathologic changes could be found in the lung.

These two problems were approached by an attempt to compare the functional capacity of the several animals with that of normal animals of approximately the same size and weight and subjected to the same strain. The second problem was studied by the gross and histologic appearance of the organs and will be discussed later.

No satisfactory mechanical device could be used to study the functional competency of respiration. It was decided that the capacity to do work would be an accurate index of respiratory competency. Accordingly, a distance of four-tenths of a mile was measured on a road that ran down a gently sloping hill. The animals operated on were each paired with a normal dog and then allowed to run down and back up the hill to the starting point.

It seemed to make no difference to the animal's ability to perform this strenuous exercise whether his phrenic nerve was severed or not, and one animal whose whole diaphragm had been paralyzed seemed to fare as well as his normal mate.

In three of the animals the phrenic nerve had been anastomosed with the recurrent laryngeal; these animals could be separated from the others because of the stridulous breathing. They were not in any way embarrassed, however, in their ability to perform the work. They ran freely and without evidence of fatigue or dyspnea. Two of them, in fact, were eager to run and actually dragged their more sluggish though normal mates.

A jury of disinterested observers, unacquainted with the animals used in the experiments, was unable to segregate the normal dogs from those subjected to operation except in the cases of those who had been subjected to combined operation on the phrenic and recurrent laryngeal nerves. Perhaps if the exercise had been so strenuous as to produce exhaustion, the normal dogs would have failed less quickly than the others. This was not done as it was desired to determine rather, whether the operation would produce a disability incompatible with the performance of the more nearly normal requirements of life. Compensation seems to be adequate to protect the respiratory function against failure during the performance of ordinary activities.

#### INFORMATION OBTAINED AT NECROPSY

The animals were killed by overetherization. Before death the tracheal overflow was obstructed in order to keep the lungs in an expanded condition. After death the thoracic wall was removed and the lungs were observed while still expanded. In one instance, namely, when both phrenic nerves had been severed, passive congestion was seen at

# THE PHYSIOLOGIC EFFECT OF PHRENIC NEURECTOMY\*

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The use of phrenic neurectomy in the surgical treatment of pulmonary tuberculosis has enjoyed increasing popularity within the last two years. It is not especially a new operation, nor is it one that is usually adopted alone, but rather in association with other surgical procedures. All work of this type is designed to give the lung its maximal amount of rest. Similar, although less, work has been done in nontuberculous cases.

In a general way improvement has been reported, but the presence of lesions within the lung has made it almost impossible to know whether or not the operation in itself will produce an appreciable alteration of the physiology of respiration.

It seemed necessary to determine experimentally the exact effect of the operation on the well-being of the patient in general as well as on his respiration. Accordingly, the normal functions of healthy animals (dogs) were observed. This included careful observation of the symmetry of the chests and the movements of the thoracic wall and diaphragm. They were operated on under ether anesthesia and with aseptic technic and the phrenic nerve was evulsed, some on the left side and others on the right, and, in one instance, on both sides. Great care was taken in the details of the surgical technic to expose the nerve beyond the point of its accessory roots, so that complete phrenic neurectomy could be effected. No immediate change was observed in these animals during the operation, and on the day following, when the animal had recovered from the anesthetic, the studies reported here were made.

To measure and compare the movements of each side of the thorax accurately, a special frame was built which could be securely fastened to a horizontal table. The horizontal bar, clamped to the table, was divided into two equal parts, and chains were fastened at its central point. Hooks were inserted into the lateral uprights at equal heights so that the height on the two sides could always be the same. The dog was placed on its back with its vertebrae exactly in the middle of the frame. The receiving tambours were fastened to the animal's thoracic wall by chains, the links of which were of equal length. By this means the

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\*Work done in the Division of Experimental Surgery and Pathology, The Mayo Foundation.



duced into the trachea. Ten minutes later he was killed by overetherization, the trachea being clamped to maintain expansion of the lungs. The lungs and heart were carefully removed without injury to the diaphragm or its attachments. The lungs appeared normal in every respect; there was no evidence of congestion on either the dorsal or ventral sides or in the upper or lower lobes.



Fig. 6.—Appearance by transmitted light, showing the relative thickening of the two sides and the translucency of the paralyzed hemidiaphragm.

The left phrenic nerve was normal in size, and mechanical stimulation of its distal end caused marked muscular contraction of the diaphragm. The right phrenic nerve, however, was smaller than normal and terminated above in a scar attached to the upper portion of the

EXPERIMENT SHOWING AMPLITUDE OF MOVEMENT  
OF EACH HEMITHORAX

Normal dogs were chosen, placed comfortably on their backs on a table and securely fixed in position. They were carefully examined, especially by inspection, and no difference in amplitude of movement of the two sides could be detected. For purposes of illustration, they were placed in the special frame, tambours under equal tension were placed against their sides and a record made of the movements of each hemithorax. All of the records were a confirmation of the observations made during the original examination. The two sides showed an even amplitude of movement. On fluoroscopic examination the amplitude of movement of the diaphragm was found to be equal on the two sides. Roentgenograms of the chest were made with the chest in the position of full inspiration and the record kept for illustration and comparison with others made later when the phrenic nerves had been evulsed.

EXPERIMENTS TO DETERMINE EFFECT OF AN ABDOMINAL  
INCISION ON MOVEMENTS OF CHEST WALL  
AND OF DIAPHRAGM

Animals found normal in the previous series of experiments were anesthetized and a long incision, such as is customarily employed for an Eck fistula operation, was made through the abdominal wall. Intra-abdominal manipulation was avoided. The wound was closed according to the standard technic and the animal taken to its cage. The following day after careful physical examination records were made. Fluoroscopic examinations were made in each instance. These experiments were repeated with dogs on which an Eck fistula operation had been performed on the preceding day.

Physical examination showed clearly that the abdominal movements were decreased in excursion but that those of the chest were not altered appreciably; nor were differences seen in any instance in the movement of the two sides. These observations were confirmed by a study of the tambour records, which showed an equality of movement on the two sides, as well as by fluoroscopic examinations which revealed normal equal movement of the two sides of the diaphragm. There was no instance in which either the movements of the chest wall or of the diaphragm were influenced by the abdominal incision.

EXPERIMENTS TO DETERMINE EFFECT ON MOVEMENT OF CHEST  
WALL AND OF DIAPHRAGM AFTER SECTION OF  
PHRENIC NERVE

Dogs found to have normal movement of the chest wall and of the diaphragm in former experiments were operated on under general

it was attached to the thoracic wall. The paralysis had evidently been complete, and the atrophy was universal.

The diaphragm was then removed intact and flattened out smoothly on a ground glass plate. Fibrillary twitchings appeared in the thick red muscle of the normal side, but the paralyzed side was in repose and could not be made to show muscular movements by stimulation applied

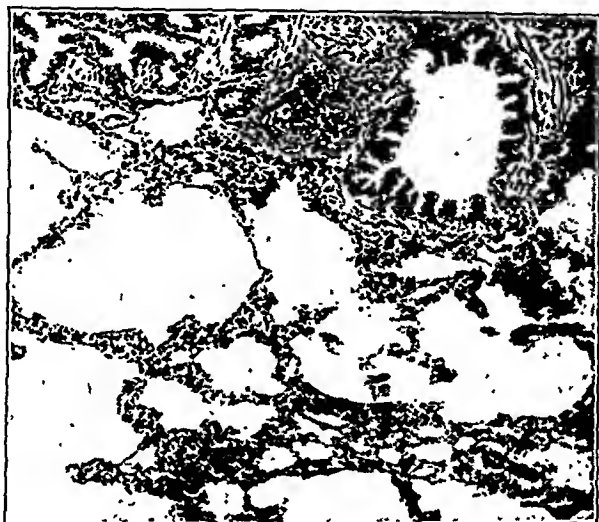


Fig. 8.—Normal appearance of base of right lung in animal with right phrenic nerve cut.



Fig. 9.—Atrophied nerve, showing vacuolization and loss of myelin sheath.

to the stump of the phrenic nerve or directly to the muscle itself. Yet either procedure brought out violent contraction on the normal side. The line of demarcation was nicely illustrated by this means and confirmed the observations made on inspection. Contractions occurred up to the line of separation when the normal muscle was stimulated, but

record showed the same amplitude of movement of the two sides of the chest wall. On fluoroscopic examination, however, striking differences were observed. The paralysis on the side of operation was apparent. Not only did that half of the diaphragm fail to move through its ordinary excursive distance but in most instances it took on paradoxical movements, passing upward on inspiration and downward during expiration. These movements, however, were always very short. Often no movement could be seen and infrequently the movements were normal in direction but showed only a small fraction of the normal excursion. The other and unaffected half of the diaphragm showed an excursion that



Fig. 3.—Left phrenic neurectomy, showing elevation of diaphragm on the left side.

was identical with its movement before the operation had been performed. In no instance could a difference in the movement of the costal margins be observed regardless of which half of the diaphragm was paralyzed or when both phrenic nerves had been evulsed (figs. 2, 3 and 4).

Section of the phrenic nerve produces paralysis of that side of the diaphragm to which it supplies motor innervation. The paralysis affects the movement of the hemidiaphragm causing it to remain stationary or to have slight normal or more frequently paradoxical movements. The

studied fat droplets were seen; with van Gieson's stain specimens showed no evidence of increase in connective tissue. When the degree of atrophy was studied, a micrometer attachment was employed to measure the size of the cells. No effort was made to obtain absolute accuracy, but it was possible to determine that the atrophic cells were approximately one-quarter the size of the normal cells. This corresponds with the judgment of the relative thickness and density when inspected grossly. The sections of the lungs showed no evidence of abnormality regardless of the side or part of the lung examined.

The lungs were examined fluoroscopically when still inflated. Iodized oil, 40 per cent, had been aspirated into both the right and left sides, showing that the paralysis on the right side did not influence respiration sufficiently to prevent aspiration of the tracheal contents (figs. 6 to 11).

#### SUMMARY

In a series of experiments on dogs, either one or both phrenic nerves were severed. The behavior of the animal and the function of respiration were studied by physical examination, a recording device and the fluoroscope. The intrapleural pressure was measured on both sides. The lungs, diaphragm and phrenic nerves were examined at necropsy, both grossly and microscopically.

The operation itself is attended with little or no risk for the patient; it brings about no impairment of his functions in general or of his respiratory function in particular. The compensation is sufficient to overcome the loss in function of the half of the diaphragm or indeed that of the diaphragm as a whole when both phrenic nerves are severed; the animal is competent to carry on its usual activities without embarrassment or dyspnea. The thoracic wall, both laterally and at the costal margins, apparently moves independently and is not influenced in direction or extent by paralysis of the nerve regardless of the side operated on. Atrophy appears early in the diaphragm, but paralysis appears at once, and the paralyzed side can be determined by fluoroscopic examination, but not by inspection or palpation of the chest, nor by tambour readings of its movement. The paralyzed hemidiaphragm rises approximately one interspace higher than its fellow and remains stationary or takes on short normal movements, or in a few instances paradoxical movements so that it may be seen to rise in the thorax a short distance on inspiration and fall an equal distance on expiration. The paralysis on the side of the section is complete and the atrophy uniform. The line of demarcation between paralyzed and normal muscle is distinct and sharply drawn. The response to stimulation is lost throughout the whole of the affected hemidiaphragm. The muscle cells are reduced to approximately a quarter of their normal size, and fatty degeneration

breathed mainly by means of costal movements, then slight movement of the abdomen, slightly accentuated on the right side. The left phrenic nerve had been severed. On fluoroscopic examination, however, the dome of the left hemidiaphragm was higher than the right ever reached and showed evidence of slight normal movement. The right half of the diaphragm maintained its normal excursion. The heart seemed to be in its normal position, and no alteration from the normal density of lung tissue could be observed.

Dog 1 illustrates the observations obtained when neurectomy has been carried out on both sides. His respiration was not embarrassed. He breathed normally with equal expansion on both sides. When the lungs filled, the abdomen relaxed, but when the lungs emptied the abdominal muscles contracted forcibly. One could not have suspected from the appearance of the animal that an operation had been performed which might have crippled respiratory function.

#### THE EFFECT OF PHRENECTOMY ON INTRAPLEURAL TENSION

It is well known that the mediastinal partition of a dog is a thin and fragile membrane, and that fluids as well as air may pass from one side to the other. Pressure, therefore, should be equalized regardless of the unilateral lesion inflicted, and the opposite side should sustain a burden in compensation so that respiration may be unimpaired.

It seems probable, therefore, that pressure readings in experiments on dogs cannot be interpreted as accurately portraying conditions in man, subjected to a similar experiment. Yet compensation is a fundamental function in all animals and concerns physiologic phenomena consequent on section of a motor nerve for the purpose of determining the crippling effect on respiration as a whole and on the relationship existing between the several groups of muscles whose concerted and correlated action makes breathing possible. To this end, simultaneous readings were made from each side, employing a pair of manometers mounted side by side (fig. 5).

The size of the animal and the character of its breathing during anesthesia seemed to affect the amplitude of movement and create greater or less variations between the two phases of respiration. Thus, it became difficult to establish a normal negative pressure reading that might apply to any animal or, in fact, to a single animal under varied circumstances. Yet the readings on the two sides were invariably approximately the same whether they were taken on normal dogs, on dogs with both phrenic nerves severed, or on dogs with only one nerve severed, and regardless of whether the right or the left nerve had been destroyed.

The accompanying table illustrates the variables and the similarities of the readings. The dogs were under ether anesthesia while readings

# THE LOGICAL SEQUENCE IN TWO-STAGE THORACOPLASTY

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In deciding on an operative course in cases of pulmonary tuberculosis, there should be a full review of the progress of the disease from the beginning and a particularly careful study of the rapidity and character of the changes that have occurred during the last two or three months. Treatment by pneumothorax will probably have been instituted and its result should be known. In addition to this clinical picture, a roentgenologic series is necessary. With all the data in mind, the type of operation or combination of operations may be selected from some kind of thoracoplasty, phrenic nerve avulsion, pneumonolysis or a direct procedure on the lung.

The favorite practice at the present time is to perform paravertebral thoracoplasty as elaborated by Sauerbruch, the details of which it is not necessary to review. This operation may be performed in one stage or in a series of stages, according to the pathologic picture and the patient's physical state or mental attitude.

The more usual manner of proceeding is to divide the thoracoplasty into two principal stages, the one beginning with the resection of the lower ribs, the other beginning with the resection of the upper ones.

The question I wish to take up here is the one of precedence. Following the advice of Sauerbruch, most surgeons have begun by operating on the lower part of the chest, and after an interval of days or weeks have resected the upper ribs, ending with the first.

In my earlier cases, I operated in one stage (five cases), resecting the first eight ribs only; but I soon came to the conclusion that the two-stage operation with resection of from ten to twelve ribs was preferable. The sequence having the upper part of the thorax as a first step was decided on after a study of the usual distribution of the pathologic lesions and the physiology of the movements of the chest wall in breathing.

I shall speak only of those cases in which collapse as complete as possible is contemplated, even though in the progress of the case it may be decided that a less radical procedure may suffice, with the treatment suspended after the first stage. Cases complicated by open empyema are not considered here because they demand a separate procedure—that of obliterating the infected pleural cavity, the lung itself already being collapsed or even compressed.

The danger of spilling by gravity from cavities in the upper part of the lung has been referred to as a reason for beginning with the lower

certain variations with each respiratory movement. Thus, readings of separate respirations registered — 4 to — 8, — 2 to — 6 or — 5 to — 9, but in every case there was no difference between the two sides. In this particular animal, therefore, although certain variations were noticed, there were no differences between the affected and the unaffected sides. Compensation had been so complete that the two pressures were maintained equally; careful observation failed to disclose inequalities in respiratory excursions, and the costal margins moved through their normal excursions in both distance and direction, seemingly independent of the fact that one side of the diaphragm had its normal strength while the other had become a flaccid structure lying inert a full interspace higher than its mate.

*Effect of Phrenic Neurectomy on Intrapleural Tension*

Dog	Operation	Pressure (Mm. of Water)	
		Left	Right
1	Both nerves cut.....	—3.5 to —5.5	—3.5 to —5.5
2	Left nerve cut.....	—1.5 to —4.0	—1.0 to —3.5
3	Right nerve cut.....	—1.0 to —7.0	—2.0 to —7.0
4	Normal .....	—2.0 to —6.5	—2.0 to —6.0
5	Right nerve cut.....	0 to —8.0	0 to —8.0
6	Right nerve cut.....	—3.0 to —7.0	—2.0 to —7.5
7	Left nerve cut.....	—1.0 to —5.0	—2.0 to —5.5
8	Right nerve cut.....	+2.0 to —5.0	+2.0 to —5.5
9	Left nerve evulsed.....	+1.0 to —6.0	+1.0 to —6.0
10	Left nerve cut.....	+1.0 to —5.0	+1.0 to —5.0

The reading in the case of dog 10 was more difficult to obtain satisfactorily because different respirations gave different variations between the two sides. With certain respirations, one manometer reading varied as much as 1 mm. from the other; during the next respiration, an identical discrepancy might appear on the opposite side. There seems to be a certain degree of independence in movements of the two sides and not complete uniformity either for successive respirations on the one side, or for one side as compared with the other. The majority of respirations, however, are equal in amplitude and degree of negative pressure. During expiration, the pressure frequently registers zero or even small positive values.

FUNCTIONAL CAPACITY OF ANIMALS AFTER PHRENIC  
NEURECTOMY

In the foregoing experiment, it has appeared that compensation is so powerful a protective mechanism as to preclude the possibility of danger to respiration, even though an important muscular structure has been rendered incompetent to carry out its accustomed office. Anatomically, it becomes apparent that the only effect of paralysis of one side of the diaphragm is to lessen the long diameter of the thoracic cage. The



may produce such great improvement that it may be advisable to postpone indefinitely the thoracoplasty of the lower part.

7. The general rule of surgery, that other things being equal, the more difficult part of an operation should precede the simpler, may well be applied in thoracoplasty. The patient, also, will be relieved to feel that the worst is over, and he will approach subsequent operations with confidence.

### ABSTRACT OF DISCUSSION On the Papers of Drs. Lemon and Lilienthal

DR. EDWARDS S. WELLES, Saranac Lake, N. Y.: I want to argue with Dr. Lilienthal a bit about this incision on the clavicle down to the bone. I have not tried this one, but have tried one a little higher. I used the one Dr. Alexander recommends, which is 6 cm. above the clavicle and 6 cm. long, in a transverse direction. I have gone back to the up-and-down incision at the posterior border of the clavicle, with the lower end of the incision coming about 1 inch (2.5 cm.) above the clavicle. I used to make the cut about 2 inches long and have now reduced it to 1 inch or less. I have two little retractors which I put in, one each way, cutting merely enough to allow room for the retractors. I think the important thing is to find the nerve and nothing else, as Dr. Lilienthal says. He enters the incision and says the phrenic nerve and nothing else is here. At the point at which I enter, the phrenic nerve is present and nothing else, because of the way I do it. I lift the sternomastoid muscle out of the way, and come to a layer of fascia. Then I put in my finger before separating or doing anything further and feel the anterior scalene muscle. The nerve is crossing on that diagonally, from without inward. If one finds this muscle first and exposes it, he has the phrenic nerve and nothing else. If when one has pulled the sternomastoid muscle out of the way, he begins to split the fascia, he always find a little pad of fat on top of the muscle. If that is split through and dissected by a blunt dissection, it is always easy to go down on the inside of the muscle, miss it altogether, and find that the dissection has reached the vertebrae; or one can easily go down on the outside of the muscle and run into various things. If one puts his finger in right at the start and splits the fascia on the middle of the muscle, he invariably finds the nerve and nothing else. The incision should not be 2 or 2½ inches (5 or 6.7 cm.), as Dr. Lilienthal says, but not more than an inch long. As far as disfiguring scars in women are concerned, I do not think that it makes much difference whether there is a 1 inch scar an inch above the clavicle or a 1 inch transverse scar on the clavicle. If a woman wants to cover it up altogether, she has to wear a neckpiece in her dress, or something of the sort. If she is going to wear a low-necked dress, she will expose the clavicle anyway. I do not say that this is not all right, but I think the other method is fully as good.

One objection I have to Dr. Lilienthal's method is that in operating on the left side one runs more danger of hitting the thoracic duct than in operating an inch higher up. In one case I cut the thoracic duct, and I have heard of one or two others who have cut it. This is not as serious as books would lead one to expect, but one does not want it to happen. I should be a little afraid in operating on the left side by Dr. Lilienthal's method that if the thoracic duct arched a little above the clavicle, I might strike it in dissecting the phrenic nerve.

the bases of the lungs and throughout the posterior surfaces of all of the lobes. In all the other animals, the lungs appeared perfectly normal. The phrenic nerve was traced in each instance throughout its course to determine whether or not accessory branches had been missed during the surgical operation. In one instance, a tiny twig was found passing into the main trunk below the point of section. The condition of the pericardium and heart was observed, but pathologic changes were not noticed, and, as in the pleura, no increased amount of fluid was found. The diaphragm itself showed striking changes. One animal that was killed within two days of its operation showed evidence of atrophy which was observable in the gross specimen and represented by pallor and thinning of the muscle. The diaphragm on the side of operation was approximately one interspace higher than on the opposite side, and in those animals that had been under observation for as long as three months the muscle was only a fraction of the thickness of that of its mate, pale and almost transparent. Even the hemidiaphragm in the animal that had a small unsevered branch showed marked evidence of atrophy and could scarcely be distinguished from that of other animals in which the phrenic nerves had been evulsed completely.

Sections were taken from the posterior portion of the lower, middle and upper lobe of both sides, from the phrenic nerves on the two sides and from both sides of the diaphragm. No difference could be determined on microscopic examination of these sections of the lung. Apparently no pathologic change had resulted from the neurectomy. In the one instance in which both nerves had been sectioned, evidence of passive congestion was seen. Sections from the phrenic nerves on both sides were studied under the microscope; a comparison showed definite evidence of atrophy of the nerve fibers when differentially stained. The muscle was also atrophied in all instances on the side of operation, but remained perfectly normal on the intact side.

To emphasize the effect of phrenic neurectomy a description of the observations in one case after operation and at necropsy is included. A dog was operated on, April 13, at which time the right phrenic nerve was drawn up as far as possible and evulsed. The animal was studied in the usual way. On physical examination, there was such similarity between the two sides that the side of operation could not be distinguished from the normal; the dog's physical fitness to do work was unimpaired and its intrapleural pressure was satisfactorily recorded and was bilaterally equal. The fluoroscopic examination showed that the right hemidiaphragm was paralyzed, rose an interspace higher into the thorax than the left and displayed short paradoxical movements.

On September 11, the dog was reexamined and the observations just described were confirmed. He was anesthetized with ether for twenty minutes, during which time iodized oil, 40 per cent. was slowly intro-

to be expected. If so, some of them will be placed mesially and some laterally to the muscle. With the use of the fluoroscope the operator can see the type and nature of excursion before operation and the effect on the diaphragm after he has crushed the main branch and the accessory branches are revealed. It is necessary to keep on crushing the accessory branches until the desirable end is attained; this is a paradox. Until that desirable end is obtained the maximum influence of the paralysis of the diaphragm is not obtained. There are distributions of nerves so atypical that exercises may not cause complete paralysis.

Dr. Lemon said his manometer readings were identical after paralysis of the diaphragm on one side. However, the dog has a thin pleura, and man has not. If Dr. Lemon would employ the same method but use an animal with a thick pleura like the monkey or sheep, he would find a material difference, and that that difference would be a considerable reduction but not an abolition of the intrapleural negative pressures.

We have been able to make some study of the degeneration of the human diaphragm. We know that the degeneration begins promptly, that at the end of the fifth week it is well advanced, and that motion of the diaphragm is recoverable six months after temporary block. We have tried to find out such means as would permit the induction of a temporary block, to avoid permanent reduction of vital capacity, which occurs in man. Injections of alcohol were tried but discontinued for two reasons; they are not dependable and it is difficult to inject the right amount of alcohol without spilling a little. If any does escape, the amount of neuritis that can be caused is prohibitive. It has been found that by using a small ordinary forceps, clamping it tightly, and putting four bites of the forceps along the nerve that the paralysis can be made to last approximately four months.

DR. LEO ELOESSER, San Francisco: Under the influence of Dr. Alexander, within the last six months I have performed a thoracoplasty from the top down. It is too early to speak of results; however, there has been no immediate spread of the tuberculous process since the operation.

The results of Dr. Lemon's experiments are disappointing in a way. They show that the phrenic nerve operation is innocuous—that it does not seem to make much difference whether it is done or not. Corper of Denver has performed the same experiments on man that Dr. Lemon has performed on the dog. He inserted manometric needles with both sides of the chest in unilateral pneumothorax and showed that the human mediastinum is a yielding structure, and that within certain limits the two pressures rapidly approach the same level. So far as the technic of phrenic avulsion is concerned, it really does not make much difference, it seems to me, how the incision is made. The nerve is easy to recognize in that it is the only structure in the neck which runs from above downward toward the midline. All the other structures run downward and outward.

DR. EDWARD A. ARCHIBALD, Montreal: I hoped that in this discussion of Dr. Lilienthal's paper there would be an expression of opinion from those who have had experience with the procedure as to the value of a two-stage thoracoplasty in the reversed order. Dr. Alexander proposed the method and Dr. Lilienthal has been using it, that is, first resecting the upper ribs after a phrenicotomy. I should like to know in particular what has been the experience of others as to the incidence of fresh tuberculous invasion of either lung following this procedure. The frequency with which this complication follows the standard Sauerbruch procedure of primary lower rib resection is now

pericardium. Similar stimulation of its distal end produced no response of the atrophic muscle.

The abdominal contents were carefully removed, leaving the diaphragm intact. Then light was thrown in from the abdominal side and a most striking picture presented itself. The left hemidiaphragm was almost opaque and showed only its bright red color, but the right was pinkish, thin and transmitted light so that objects could easily be seen



Fig. 7.—Appearance by direct light, showing detail of normal muscle and the line of demarcation between the normal and the paralyzed side.

through its muscular portion. Moreover, it was seen that this advanced degree of atrophy was not confined to any one portion but included the whole muscular structure of that side, proceeding from the middle line, where it was precisely separated from the normal, to the periphery where

In one of my left-sided cases of phrenic nerve avulsion, a small quantity of slightly opalescent fluid appeared during the operation which was thought to come from an injury to the thoracic duct. The avulsion was completed and the wound dressed; healing was uneventful. Knowing Costain's experience, I do not believe that ordinary slight injuries of this structure would counteract the advantages of the transverse clavicular incision. In any event, with blunt dissection the accident must be extremely rare.

One more thing about the phrenic nerve. As shown in my single picture of the immediate result of phrenic nerve avulsion, in a few days we had a high diaphragm on that side, equivalent to about 500 cc. of air. I considered that important. The fact that the dogs could work after the phrenic nerves had been operated on is not the point. We are not discussing that. We are discussing the alteration of the internal pneumatic conditions of the human chest, and they are certainly altered when there is such a considerable rise of diaphragm. I agree with Dr. Archibald that we ought to operate by graduated stages. One rib too much is a great deal worse than three ribs too few.

pericardium. Similar stimulation of its distal end produced a contraction of the atrophic muscle.

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patient. Treatment approaches the height of effectiveness as it is adapted to conform with nature's methods and with the remaining potentiality of each patient; it should be inaugurated promptly so that its most valuable factor, that of prevention, can exert its greatest influence.

Tubercle bacilli, though low in virulence, are so high in viability that, once they enter, tissues of even insusceptible hosts sometimes not only survive decades of encapsulation, perhaps in calcified lesions, but retain a measure of pathogenicity. The insusceptible are able, because of the competence of the structures providing resistance, defense and repair, to inactivate the unexpelled parasites that have escaped destruction, and to encapsulate them so promptly in rapidly healing lesions that the resulting cicatrix is too small to impair function. Susceptibility results from incompetence of the structures affording resistance, defense and repair. In consequence, the tubercle bacilli are less promptly or less completely inactivated, if inactivated at all, and the involution of the disease is slower or its evolution is indicated by the increasing number, wider distribution and less favorable characteristics of local lesions.

Local lesions are the battlefields whereon the campaign waged by the host against the invading parasites is won or lost. There is little if any difference in the vulnerability of the normal lung structure and in lung structures affected by such conditions as passive congestion, cicatrices and emphysema. The outcome of the battles—in other words, the nature of the local lesions—is therefore determined almost exclusively by the quality and quantity of the blood delivered to them. The reinforcements delivered in the cellular and noncellular fractions of the blood enable insusceptible persons to control the invaders before they can establish themselves. The blood of susceptible persons contains inadequate combatant strength and the parasites are sufficiently virile to continue their offense, which is subsequently overcome by the least susceptible, checked by the moderately susceptible and somewhat retarded by the most susceptible hosts.

Accordingly, the attention of therapists should not be diverted in the least from local lesions, but should be enlarged to include recognition of the systemic sources of native and acquired combatant influences that are present in the blood. Thus it will be possible to develop methods to protect and to improve the competence of the structures producing resistance, defense and repair, which are prerequisite not only to recovery from every disease but to the continued existence of even the most robust.

It has been supposed that the pathogenesis and histogenesis of the tubercle were established. Medlar's<sup>1</sup> contributions show this to be

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1. Medlar, E. M.: *Am. J. Path.* 2:275-290 (July); 401 (Sept.) 1926.

was observed but no increase in connective tissue. It is possible that connective tissue might be increased in amount if the animals were allowed to live more than five months after operation. No observations were made over a longer period of time.

The experimental work would lead one to believe that respiration is a complicated mechanism, made up of the combined movements of various sets of muscles each so controlled that coordination of movement is maintained, yet each so independent of the other that it may be put into dysfunction without disturbing the action of any others, singly or combined. Compensation is highly developed and a factor of safety, so that the animal crippled by the loss of even so important a structure as the diaphragm may not only survive but be competent to live an active and a normal life. The alternative presents itself for consideration. It may be true that the importance of the diaphragm has been overestimated.

Section of one phrenic nerve causes paralysis and atrophy of the entire hemidiaphragm on the same side. After five months there is no evidence of cross innervation or of regeneration. Moreover, the evidence seems clear that the periphery of the diaphragm throughout its whole circumference suffers atrophy. If the branches of the intercostal nerves innervate this portion, their usefulness would appear to be extremely small and insufficient to prevent atrophy equal to that in other and remote areas, or to permit of contraction when the muscle is stimulated.

Paralysis of one half of the diaphragm fails to affect respiration to the extent that aspiration of tracheal contents is prevented. The size of the thoracic cage is decreased in one dimension only. This reduction of volume produces no physiologic alteration from normal.



of hematopoietic cells, manifest in advanced anemia, in the distorted proportions of leukocytes, in diminished blood volume and in hastened sedimentation rates, is more surely and rapidly corrected with transfusions of unmodified blood, repeated until recovery is established. Expatients, particularly those who have recovered from more active forms of tuberculosis, are beneficial donors. The paraffined tube method is dependable.

Transfusions are not without danger even though the blood of donors is most carefully checked against that of recipients and incompatibility is eliminated. Thrombosis and embolism occur, although rarely. Too rapid introduction of blood will dilate and incapacitate the right side of the heart, which is often the determining factor in recovery. Preserved blood—or blood treated with available anticoagulants—adds little besides increased oxygen-carrying power and should be used exclusively for those exceptional patients who are not toxic but who are gravely anemic.

2. *Increased Amount of Blood Delivered with Least Cardiac Labor.*—According to Cloetta, the largest unit volume of blood is delivered to a unit volume of lung with the least cardiac effort when intrapleural negative pressures are reduced but not abolished. The vessels of a lung in this position of incomplete deflation offer the least peripheral resistance to the flow of blood. Peripheral intravascular resistance rises if the intrapleural pressures become atmospheric and the lung is in collapse, and is progressively much greater if the intrapleural pressures become increasingly positive and the lung is correspondingly compressed.<sup>2</sup> Experimental and clinical observations have demonstrated<sup>3</sup> that optimum reduction in intrapleural negative pressures follows inactivation and consequent upward displacement of the diaphragm. Under these conditions the deflated lung continues to function; there is neither hyphemia nor cellular deterioration from lack of use. The improved circulation resulting from the diminished peripheral intravascular resistance manifests itself in increased powers of pleuropulmonary resistance, defense and repair, which are probably at their best. Moreover, this is a defense response which occurs naturally in man and in animals in response to most acute and to some chronic irritations of the lung and pleura. It can be induced effectively by blocking the transmission of motor impulses through the phrenic nerve.

However, there is another noteworthy aspect. Individual competence, the ability to develop energy in excess of the amount required

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2. Yates, J. L.: Effects of Acute and Chronic Pneumothorax, *Am. J. M. Sc.* 165:1 (Jan.) 1923.

3. Yates, J. L.: The Significance of Vital Capacity in Intrathoracic Therapy, *Arch. Surg.* 10:477 (Jan.) 1925; The Significance of Vital Capacity in Intrathoracic Therapy, *Arch. Surg.* 12:257 (Jan.) 1926.

ribs, and this seems to be the principal theoretical ground for delaying the upper stage.

Briefly, the following are my reasons for preferring to resect the upper ribs first:

1. The advanced lesions, particularly cavities, are more frequent in the upper lobe, or even in the apex, than in the lower. The resection of the first five or more ribs has an immediate beneficial influence on the seat of the main lesions.

2. As the operation is performed under local anesthesia, the danger of overflow is practically nullified by the patient's voluntary effort to expectorate, the principal power of the cough being applied by the lower, more freely moving ribs.

3. The compression exerted on the contents of the chest by the mobilization of the upper ribs is more gradual than that which is encountered on resection of the lower ribs, because for obvious mechanical reasons it is practically impossible to exert direct force, as by a bandage, on the apical portion. The effect is secured partly by muscular action and partly by negative intrapleural pressure so that sometimes the final result is not obtained for weeks or even months after the operation. There is, however, an immediate and considerable reduction in the capacity of the apex, sometimes amounting to its obliteration, because the first rib almost always drops so that its distal cut surface is from one to two interspaces lower than the cut surface of its vertebral portion.

4. The physiologic changes due to the mechanics of the operation on the upper part of the thorax do not cause such serious derangements of function as those following the operation in the lower part of the chest, where the amplitude of respiratory motion is greater. The most serious of these derangements is displacement of the mediastinum toward the healthy side, and this is much less marked in the upper part of the chest than in the lower. When the time has arrived for the second stage, a partial adjustment to the altered state will have taken place so that there will be less shock from the displacement of the more mobile parietes in the lower part of the chest.

5. It is essential that the first rib should be resected in order to secure rapid and good collapse of the apex. Then, too, this rib is the keystone on which depends the drop of the ribs immediately below it, say the second, third and fourth, and there is doubtless an effect on the position of those lower down. Manifestly, then, the greatest possible reduction in the size of the hemithorax will not be secured unless this rib is cut. It should therefore be divided at the first stage, before the resected ribs below have become fixed in their new positions.

6. If the phrenic nerve of the same side has been avulsed previously, attack on the principal lesion by resections of the first five or six ribs

acute or subacute adenitis may reawaken a process of the lymph glands, or a lymphotoxic disease, notably influenza, is followed by renewed activity of a pulmonary affection. Retained health is purchased by constant vigilance.

#### SPECIFIC SECONDARY OBJECTIVES

1. *Alteration of Intrathoracic Tension.*—Thoracoplasty employed in treating pulmonary tuberculosis, like arthrodesis used in combating certain forms of joint tuberculosis, is still supposed by some to be indicated almost as soon as a diagnosis is made. Thoracoplasty, like arthrodesis, is only a means to aid healing of a local lesion, a means to be avoided, if possible, because of permanently impaired function. The function impaired by costectomy is external respiration, which is fundamental to life, and the extent of the impairment is measured by the reduction in vital capacity. Vital capacity is normal when mobility of parietes is unrestricted, intrapleural negative pressures are within usual limits and pulmonary elasticity is unimpaired, provided that proper amounts of good blood are delivered through the lungs under appropriate pressure. Pulmonary tuberculosis tends to reduce vital capacity by impairing both the breathing and the circulatory units. No more reliable indication of the efficacy of treatment need be sought than vital capacity, which should be reduced as little as possible during the acute phase of the disease and returned as near to normal as possible during convalescence.

If the object of thoracoplasty is to immobilize and to compress the lung, a consideration of the harmful effects of immobilization and compression which are not produced, even though costectomies are radical, might have a deterrent influence on its overenthusiastic advocates. Immobilization of any structure imposes deterioration on the cells affected, a progressive atrophy that tends toward necrosis and therefore reduces local resistance. It likewise produces hyphemia, which restricts the delivery of reinforcements needed to promote local defense and repair. Compression of the lung is not attainable even with complete thoracoplasty, but merely collapse, because the intrapleural negative pressures are replaced by atmospheric and not by positive pressure. But collapse restricts function, reduces the amount of blood delivered and increases the load on the right ventricle because intravascular resistance is raised.

The reasons for the good effects of thoracoplasty also establish its indications. Recovery from tuberculosis depends on healing of the local lesions. The healing in the insusceptible is so perfect that the resultant cicatrix may be undetectable, or so slight as to be negligible in its detriment to function. Destruction of lung substance is minimal. The repair of slightly more advanced lesions in which destruction of pulmonary tissue is less restricted produces a scar. If the cicatrices

As far as drainage is concerned, I always used to drain as Dr. Lilienthal says. Now, when I make the small incision and blunt dissection described to reach the nerve, putting in no tie, I cut no vessels except in the skin. In the last twenty or twenty-five cases, I have put in one small subcutaneous suture, starting at one end of the cut, going back and forth and emerging at the top, with no drain. So far I have had no collection of serum inside that I have had to drain; there are no stitch holes after this method is used, and the scar is almost imperceptible.

As to Dr. Lilienthal's method of performing thoracoplasty, I think he is right. I believe that what he says about the lack of danger of pushing down secretions from the upper lobe cavities into the lower lobe is true, because the lower ribs are the ones used for coughing and expelling secretions. If the lower ribs are left intact, there is no danger of pressing secretions from the upper lobe down, because even if they do go down, the patient can cough them up. Patients cough much better after an upper stage thoracoplasty than after a lower stage operation. I have been doing most of my operations in that order lately, and have preceded practically all of them with a phrenicotomy. I think it is well to do a phrenicotomy first before attempting thoracoplasty downward. In the first place, the patient raises more easily after phrenicotomy and, as Dr. Lilienthal states, in a good many cases fewer ribs can be taken out. I have not had any cases in which I could resect only the upper five, but I have had a number of cases in which I could stop at about eight or nine, instead of resecting the full eleven; the diaphragm rose up as far as the ninth rib, or even to the eighth, and I found that after taking out the upper eight ribs and then making a roentgen-ray examination to see how much collapse there was, that I had reached the diaphragm and that it would be a waste of time to remove the ninth, tenth and eleventh ribs.

Dr. Lilienthal spoke of doing the worst stage of the operation first. Technically speaking, it is true that when one has the upper stage done he has completed the hardest job, as far as the surgeon is concerned, but I think the contrary is true as far as the patient is concerned. The lower stage is the dangerous one. It is all right to tell the patient that the worst stage has been done, provided the surgeon does not let himself believe that his worries are over. I find that patients do not have much shock after operations on the upper part of the chest or suffer much afterward. I do not think the upper stage is nearly as dangerous as the lower. The upper one should be completed and then the lower stage approached with fear and trembling if the patient is very sick. One should proceed cautiously and stop at any time that the pulse gets weak, because it is following the lower stage that mediastinal flutter and circulatory embarrassment occurs, if at all.

DR. JOHN L. YATES, Milwaukee: Dr. Lemon's pictures showed that in dogs as well as man the motor fibers conducting motor impulses to the diaphragm are not of necessity included in the main phrenic trunk in its cervical portion. If one operates on a series of patients to produce temporary block, one finds that three of five people have all the motor nerves in the main phrenic branch. In the other two some of the fibers transmitting motor impulses are distributed in accessory branches. The main branch may be one, two or three. In attempting to produce temporary block, it is necessary to operate on these patients on the fluoroscopic table. Dr. Welles' injunction to locate the anterior scalene muscle as soon as the incision is made is the keynote to success. After the anterior surface of this muscle has been cleared by blunt dissection, one can quickly tell by the size of this phrenic trunk whether accessory branches are

none has been subjected to any recognized danger that seemed unwarranted; neither has operative assistance been denied any patient whose complications were not of necessity fatal. The purpose has been to provide patients with opportunity for extension of life as well as recovery and not to accumulate statistics that might be imposing.

At first only those more seriously affected were subjected to operation. Some improved remarkably; then others consented; some asked to be given similar opportunities. Gradually, the less seriously sick are being subjected to phrenemphraxis. Records of physical, roentgen-ray, blood and sputum examinations and of vital capacity estimations have been kept, in addition to the usual history sheets. A summary of the more essential facts accumulated will be given. The particular purpose is to indicate the benefits obtainable from consecutive treatments based on the natural responses, with special reference to sunshine, transfusion and nerve blocking.

*Means to Improve the Quality of the Blood.*—The values of rest and diet are established. A more difficult matter is to secure cooks of proper competence, particularly when pay is restricted and employment is on a civil service basis. The management of few institutions unhampered by legal restrictions is seldom able to appreciate that money spent for high grade foodstuffs is largely wasted if preparation and service are mediocre.

The beneficence of sunshine for most patients, if it is not permitted to raise the metabolism too high, is not sufficiently appreciated. Facilities at Muirdale for living all the year in fresh air with opportunity for direct exposure to sunshine are still limited. The greater improvement of those who are in the pavilion provokes jealousy of many it cannot accommodate. Moreover, the anxiety of those accustomed to it to return when they have been transferred to other quarters after operation confirms the impression of its value. Other suitable quarters are to be supplied.

Transfusions have not been used as frequently as indicated. There has been difficulty in providing donors. Enough observations have been made to show that a patient suffering from advanced lesions, but with some reserve competence, can be given a necessary boost toward recovery with one transfusion whereas another whose local disease is less advanced but whose reserve powers have been dissipated will profit little from several transfusions. Extraordinary care must be used in selecting donors and in the methods employed. A serious reaction provoked by ill-suited blood or by methods that bruise it mechanically and alter the blood chemically may suffice to cause a fatality. Heart muscle, already fatigued and intoxicated though not irrecoverably impaired, is unable to withstand added stresses, particularly if they are added abruptly. Hence,

known. One wishes to compare the two methods. It seems to me that the reversed procedure depends for its adoption on the demonstration of its capacity to lower the incidence of the spread of infection after operation. That, indeed, was the initial thought in Dr. Alexander's mind for reversing the procedure. On that the ultimate decision rests. I have reviewed my own figures in that respect carefully. I have also reviewed Brunner's statistics of 117 cases carefully, as Alexander did. I fail to find in the rest of the literature, except for an occasional half dozen cases or so, accurate case reports sufficiently lengthy to enable one to form an independent judgment. Consequently, this particular question is still undecided. I hesitate to reverse the order of procedure, because I find that in my own figures (in practically all cases thoracoplasty being performed from below upward and in two stages) the incidence of death from fresh tuberculous invasion is so low that I cannot understand how one could expect lower figures from the reversed procedure. Those figures are briefly that in ninety cases of posterior thoracoplasty, of which seventy-eight were total and twelve partial, the latter being performed because in most of them there was an artificial pneumothorax over the lower part of the lung, only three deaths occurred from the spread of tuberculosis. One of these was on the eighth day after a one-stage procedure, one on the sixth day after a simple phrenicotomy, and one in the fourth month. In the last, the responsibility of the operation might easily be doubted. The incidence of death from pneumonia following total posterior thoracoplasty is as low as 2.2 per cent.

The argument is sound theoretically; practically, I question it. Dr. Alexander speaks of the high mortality from the spread of tuberculosis as reported in the general literature, taking his figures chiefly from the German and Swiss reports. My own feeling is that in this country things are done differently. There are other factors to be considered besides the order of rib resection. For instance, in the older countries they do not understand anesthesia as we do. On the other hand, they have been using local anesthesia, freely, which predisposes to infection of the wound, and this predisposes to pneumonia. I counted forty-six infections of the wound in 117 cases as reported by Brunner, of which six were so severe as to cause death. Such fatalities do not occur in this country. In wound healing we can do better than that. The argument is complicated. Success does not depend on one factor; it depends on many factors. Until reports have been compiled of a sufficient number of operations by the reversed procedure, from above downward, showing an incidence of spread of tuberculosis as low as that of the ordinary procedure, I should hesitate to change the order. I still feel that Sauerbruch's warning as to aspiration pneumonia of the lower lobe when the upper ribs are resected first is justified.

DR. HOWARD LILIENTHAL, New York: In answer to Dr. Welles. I would say that I did not go into the details of the operation. To palpate the anterior scalene muscle is the general practice. He says that it does not matter whether the scar is in one place or in another; but we have learned that in working about the neck, scars in the sagittal direction will tend to spread and produce keloids in many cases. These ugly scars also become indrawn. If the incision is made on the clavicle, the bone afterward supports the tissues so that there is not the slightest indrawing or the slightest dimple. This transverse scar is practically invisible at the end of about six months.

I use no skin sutures, but I employ metal clips wherever I can and take them out in four days. They leave no marks. If left in for more than four days, they may leave small suture points for a time.

Exeresis has been performed sixteen times at first operation when a permanent block seemed indicated and twice after a temporary block proved insufficient.

*Effects of Diaphragmatic Paralysis.*—Immediately after induction there is often tachycardia for a day or two; coughing and expectoration are increased and a rise in temperature is frequent. Intrathoracic distress is usually reduced if it has been present. Then general improvement is the rule. The patients feel so much better that their testimony must be discounted. Coughing and expectoration decrease; there is diminished activity; the temperature is lower; the blood improves and vital capacity is higher. Improvement in the more fortunate is continuous. In others it is maintained until the diaphragm regains motion. In some the improvement lasts for a month or two and then they begin to retrograde. Improvement in the least fortunate is largely imaginary

*Effects of Nerve Block on Ninety-Four Patients*

	No. of Patients	Phrenem-phraxis	Exeresis	Both Phrenem-phraxis and Exeresis	Im-proved	Unim-proved	Died
Group I: Far advanced bilateral; prognosis unfavorable.....	12	8	3	1	6	1	5†
Group II: Far advanced unilateral; prognosis unfavorable...	22	9	8	0	16*	4	2
Group III: Moderately advanced, pleural adhesions; pneumothorax impossible.....	43	39	3	1	40	2	1
Group IV: Moderately advanced, no pleural adhesions; pneumothorax possible.....	14	14	0	0	12	1	1
Group V: Incipient but active....	3	3	0	0	3	0	0

\* Five of these patients were subjected to thoracoplasty. In two, one stage sufficed; in one, two stages, and in two, three stages were required.

† No death in the series resulted from operation.

and born of hope. None, so far as can be determined, has been injured except the patient who died from an unrecognized contralateral spontaneous pneumothorax, and this occurred before the present staff organization was effected.

The effects of nerve block on ninety-four patients observed long enough to be indicative are given in the accompanying table.

#### FIVE GROUPS OF PATIENTS

A review of the observations made has established errors, principally of omission, and suggests corrections. The number of our patients subjected to treatment is too small and the periods of observation too limited to justify more than tentative opinions. However, most of the patients were under observation for months, some for years, before special treatment was begun. The majority have been under continuous observation since. Their progress has been compared with that of other patients with similar conditions and, except for operations, given the same care. So, too, it has been possible to compare the effects of trans-

# RATIONALE OF OPERATIONS HELPFUL IN PROMOTING RECOVERIES FROM PULMONARY TUBERCULOSIS

J. L. YATES, M.D.

MILWAUKEE

All who escape untimely death from other causes are infected with tubercle bacilli. The majority are insusceptible and develop no recognized evidence of infection. The minority are of three grades of susceptibility. Those of least susceptibility recover spontaneously, often despite maltreatment. The moderately susceptible may recover if aided promptly and properly, or may arrest the progress of the disease spontaneously. The disease in the most susceptible may be arrested if treatment is favorable, or its progress may be only retarded.

The strength or weakness of resistance, defense and repair determines insusceptibility and the grades of susceptibility. Because they are the products of activities of cells, they are not static but dynamic, and are constantly fluctuating. Fluctuations are irregularly periodic and tend to take two courses. The more common course is downward. Through fatigue and exhaustion caused by unhygienic living, by intercurrent diseases and by age, people tend to forfeit more or less of their inherent stamina. Thus, insusceptibility may be replaced by susceptibility and the grades of susceptibility are intensified. Exceptionally, persons inherently of less competence live so wisely as to develop and to conserve the strength of their combatant cells. They become less susceptible or may even acquire insusceptibility.

The primary therapeutic aims are to prevent the insusceptible from becoming susceptible, to lessen degrees of susceptibility and to restrict exposures to infection. Secondary objectives are to employ without delay every means to aid in checking the progress of the disease, to enable each patient to approach as expeditiously and as closely as possible to the status conferring insusceptibility, and to maintain that highest level of improvement against the constant menace of recrudescence.

The specific obligations of treatment are to reduce offense, to augment defense and to conserve energy. The means to fulfil these obligations are the exclusive property of no school or specialty. They cannot be determined by human authority although they must be modified by experience. They are established by knowledge of the focal and disseminated destructive actions of tubercle bacilli, the local and systemic responses provoked and the existing offense-defense ratios in each



## THORACOPLASTY

Experience in performing costectomies on patients prepared by previous nerve block and perhaps transfusion supplementary to proper hygienic measures is limited. All told, eleven patients have been subjected to twenty-two resections, although only five are included in this series. The following points have been established: Nearly complete removal of each rib is more desirable than incomplete resection. If a few ribs are removed at one operation and intervals between operations are sufficient, the number of ribs finally resected, from three to eleven, is determined by individual requirements. Healing is excellent, and, except for accidents, which are largely avoidable, death almost never occurs. Failure to urge costectomy has been responsible for the failure of some patients to recover.

## ERADICATION OF IRREPARABLE LESIONS

As stated in the foregoing, no operation that eradicates the lesions completely has been performed. The need of patients for the relief given only by operation makes it necessary to assume risks and to determine the safest procedures. To the present time, progressive cauterization as conceived and ably executed by Graham offers a probable solution.

## SUMMARY

A proportion of patients seek help after they are beyond relief. Another proportion, those of the highest grade of susceptibility, are doomed. The balance will be given the best opportunity for recovery if measures are employed without delay to augment and conserve their powers of resistance, defense and repair by cooperating with nature.

The means to cooperate with natural processes are not defined by dogmas of therapists but by biology, not by erroneous human doctrines that fluctuate with a current popularity, but by immutable laws of nature. The object is to improve the quality of blood in circulation, to increase the quantity delivered to the local lesions and to conserve and develop the competence of each patient.

Available methods are in part nonoperative, in part operative. When employed in conjunction so as to provide each patient with opportunity for undelayed recovery without undue danger and distress, they constitute the most effective treatment.

The obligation is not to determine whether any given procedure is superior to any other, but what combinations of all methods, old and new, can be the most helpful to each patient.

The purpose of this article is to suggest the rationale and to illustrate the effectiveness of transfusions of blood and of induced paralysis of the diaphragm when used to supplement other methods, one of which should be suitable exposures to the direct action of sunshine.

erroneous and provide bases for a broader and more accurate conception of the entire process. This indicates that conceptions of the nature and sources of the constituents of the blood that combat the activities of tubercle bacilli *in vivo*, woefully limited as they are, are subject to revision. Nevertheless, enough facts are established to justify alterations and innovations in clinical methods. For example, it is known that the mother cells of the various blood corpuscles are irritated by the products of the activities of tubercle bacilli, particularly the erythroblasts, neutrophilic myelocytes, lymphoblasts and megakaryocytes. In consequence the blood picture is altered; some changes are beneficial, others detrimental. Hastened sedimentation rates have demonstrated untoward alterations in constituents of the plasma. Moreover, it is known that during intervals of improvement, and more particularly with continued progress toward recovery, the detrimental alterations in cells and in plasma tend to disappear.

Consideration of all established facts permits recognition of the objectives of treatment and simultaneously indicates feasible measures. The objectives are twofold: primarily, to promote permanent recovery from the disease by helping to increase and to sustain the competence of structures providing resistance, defense and repair, that is, all structures concerned in the production and delivery of blood, the entire circulatory apparatus; secondarily, to assist patients to combat lesions they are unable to control spontaneously.

The specific primary objectives are: (1) to improve the quality and maintain a proper volume of blood in circulation; (2) to increase the quantity of blood delivered to affected lungs and to minimize the expenditure of cardiac energy, and (3) to encourage effective hygienic living afterward.

Specific secondary objectives arise after the primary have failed. They are (1) alteration of intrathoracic tension by repeated costectomies so that after requisite spontaneous readjustment the lung will receive enough good blood to effect repair, and (2) eradication of such lesions as prevent recovery and cannot be repaired.

#### SPECIFIC PRIMARY OBJECTIVES

1. *Improvement of Quality and Maintenance of Volume of Blood.*—The sources of energy for tissues, including the hematopoietic, are ingesta and sunshine. So long as cells concerned in blood production are neither overfatigued by replacing blood lost through destruction or hemorrhage nor incapacitated by intoxication, they can recover spontaneously if their burdens are reduced. Rest, suitable diet and exposures to the direct action of sunshine, controlled according to the regimen of Rollier, suffice to reestablish their integrity and function. Greater incompetence

do with the progression of the disease: when the patient gets better, the diaphragm again begins to move. I think for that reason alone that nature seems to be pointing the way toward the treatment that Dr. Yates has given these patients, both by operating on the phrenic nerve and by the other forms of therapy that he has employed.

DR. A. L. LOCKWOOD, Toronto: I wanted to ask Dr. Yates just one question in regard to phrenicotomy in an entirely different matter from thoracic work. I think you all appreciate the fact that the mortality in ventral hernia is high in people over a certain weight. We made a study of people weighing more than an average of 165 pounds (74.8 Kg.), and I would be ashamed to tell you what we found the mortality to be. Last year it occurred to me to question whether it would be feasible or whether we could get sufficient change in intra-abdominal pressure following phrenicotomy to make it justifiable to inject the nerve before attempting repair of ventral hernias in obese patients. We would relieve the pressure just enough so that probably we could operate on a larger number of these patients with less risk. I am not absolutely convinced as to the value of living fascial sutures, although I have used them only eighteen times. I have followed a fair number and have not been absolutely convinced, because one of the patients I have in my care at the present time has had one repair. He has a tremendous abdomen. I do not know how to treat it. I should like to know Dr. Yates' opinion as to whether the injection of the nerve to give temporary relief on one side would relieve the intra-abdominal pressure sufficiently.

DR. JOHN L. YATES, Milwaukee: Abnormal spastic contractions of the diaphragm preceding flaccid relaxation and the forcing of the diaphragm into a high position occur in man and in animals when irritations of either visceral or parietal pleura are induced or develop spontaneously. Besides the clinical observations indicating the efficacy of improving the quality and increasing the quantity of blood delivered to lungs in helping patients to combat tuberculosis, other studies have shown that animals and man, whether suffering from acute or chronic pleuropulmonary diseases and wounds, could be similarly benefited. We are convinced that pleuropulmonary resistance, defense and repair are at their best when the lung is in a position near that of mean inflation and its excursions above and below this mean are restricted. We believe this position is assured by paralysis of the diaphragm and is manifested in natural defense responses.

It should be recognized that there is one unavoidable danger from phrenic-phraxis. A certain amount of compensatory emphysema is produced in the contralateral lung. If there is a superficial lesion of this lung, it may rupture and produce a spontaneous pneumothorax which, if unrecognized and unrelieved by aspiration, can cause death. This accident, though rare, is noteworthy because it is easily recognized and remedied.

Dr. Archibald asked what effect is produced on the apex of the lung when the diaphragm is paralyzed. If the chest is free from adhesions, the reduction of intrapleural negative pressures affects the entire lung, and a rather homogenous incomplete deflation results. If there are adhesions about the basilar lobe sufficiently firm to prevent the diaphragm from being displaced upward, the total effect, especially on the apex, will be reduced or absent. This has been established clinically by the futility of employing diaphragmatic paralysis in combating lesions of the lower lobes, particularly in bronchiectasis.

Dr. Lambert is requested to refrain from spanking our pet child too hard. The quality of blood in circulation must be improved if patients are to realize full opportunities for recovery. This is basic to all therapy. It is scarcely less urgent to increase the quantity of blood delivered to local lesions, particularly

to support inactive existence, depends on internal respiration, which is commensurate with vital capacity. Vital capacity is materially reduced by inactivation of the diaphragm; hence, the wisdom of inducing, whenever feasible, a temporary block of the phrenic nerve (phrenemphraxis)<sup>4</sup> rather than assuring a permanent paralysis of the diaphragm by exeresis or radical phrenicotomy.<sup>5</sup> Thus, persons who recover are not irreparably handicapped by the treatment they have received.

3. *Hygiene in After-Care.*—A little can be added to the established details of after-care. Periodic physical and roentgen-ray examinations of the lungs are insufficient. Determination of vital capacity and blood examinations, inclusive of differential counts and estimations of sedimentation rates, will occasionally reveal incipient recrudescences before they may otherwise be recognized, and usually indicate the seriousness of the problem. At such times a transfusion or two will accomplish much toward reestablishing a proper margin of safety, a greater preponderance of defense over offense. It is too seldom recognized that patients suffering from any form of tuberculosis are never cured. However complete the recovery or how protracted, those who have suffered from the disease will usually carry living organisms sufficiently pathogenic to renew their attack if the encapsulating lesions are disturbed and if the systemic sources of defense are weakened. Therefore, repeated reinfection is inevitable. The danger is illustrated by the frequency with which an

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4. Yates, J. L.: *Operations as Adjuncts in the Treatment of Pulmonary Tuberculosis with Special Reference to Induced Diaphragmatic Palsy*, Wisconsin M. J. 25:273 (June) 1926.

5. The fibers that conduct sensory impulses from the tendinous portion of the diaphragm and motor impulses to the larger portion of its muscle are united in the phrenic nerve in about three out of five persons. The less typical distributions in the others are too numerous to describe or even to remember, were they all recorded. It suffices to know that instead of the main trunk two, perhaps three branches, may lie on the scalenus anticus muscle. Or there are accessory branches lying lateral or mesial to the muscle. Some may contain only sensory fibers. When attempting to cause a temporary block, and crushing is the most dependable method, it is necessary to locate all branches that transmit motor impulses. The presence of accessory branches will be suspected when the main trunk is unusually small. Then an effort is made to discover nerve twigs in the common and uncommon positions. Operations are performed on a fluoroscopy table. As nerves that bear motor fibers are crushed, the diaphragm contracts and then relaxes. Relaxation is complete, and a paradox appears when all the motor impulses are blocked. If the degree of immobilization obtained is insufficient, search for additional branches is continued until the desired result is obtained. Permanent paralysis is readily produced by exeresis unless the pleural adhesions are extraordinarily dense. Then the amount of traction required and the distress are prohibitive. It has sufficed to withdraw as much of the nerve as seems safe, cut distally as low as possible, and resect the proximal portion. One may not expect always to succeed in producing a complete paralysis. Exeresis rarely fails.

# ACCESSORY THORACOPLASTIS OPERATION FOR COLLAPSE OF LARGE TUBERCULOUS CAVITIES

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One of the most discouraging features of the surgical treatment of pulmonary tuberculosis is the failure of apical cavities to collapse completely following paravertebral thoracoplasty. In a fairly large proportion of the cases in which there is a cavity of large size, on examining the postoperative roentgenograms, one finds that the cavity is reduced to one half or one third or even one fourth of its former dimensions. It is a natural tendency to regard this as a good result, and the surgeon is inclined to consider the case as satisfactorily completed and to hope that in the following six months the remaining space will close in by natural processes of fibrosis and shrinking of the whole lung. Too often, however, this further collapse does not occur, the patient continues to raise several ounces of sputum every day, and the cavity is found to be just as large as it appeared in the roentgenogram made immediately after operation, or even slightly larger. The next procedure to undertake is a difficult question to decide. To operate again in the back and attempt to remove the plates of bone that have reformed from the periosteum left at the previous operations and to take out further sections of ribs under the scapula is a procedure the difficulties of which can be appreciated only by one who has attempted it. When these difficulties are overcome, the resulting compression may be disappointing and make no alteration in the size of the cavity. Anterior apicolysis is probably the operation of choice, as by this method the apex of the lung with its parietal pleura can be peeled downward, forcibly compressing the cavity. One of the various types of plug must then be employed to fill in the top of the chest, obliterating dead space and keeping the lung from reexpanding. The fat transplants of Tuffier and the paraffin or gauze packs used by the Germans have not attained popularity in this country. The pedicled muscle flaps proposed by Archibald seemed at first to offer a satisfactory solution to the problem. Unfortunately, however, in thin persons the muscle transplant is not sufficiently large. Even when most of the pectoralis major and all of the minor is used, and even in those cases in which the flap appears adequate, there are later shrinkage and contraction which diminish the apical compression. The operative shock following apicolysis is fully as great or greater than that produced by posterior thoracoplasty; there is always the risk of breaking into the cavity during the difficult separation of the pleura from the ribs, and on the whole the operation is far from satisfactory.

are sufficiently numerous, the total effect is to cause fibrosis and impaired pulmonary elasticity and to alter intrathoracic tension. Other more advanced lesions associated with greater destruction of lung substance cannot heal because the contraction of the scar necessary to permit complete repair is prevented by the contrary parietal traction transmitted usually through pleuritic adhesions. Hence, if enough ribs, which have acted like the ridge pole of a tent and prevented contraction, are removed so as to permit of contraction, repair will be fostered if the blood supply is adequate.

Hence, the plan is to begin operative treatment not with thoracoplasty but with improving the quality of the blood and by inducing paralysis of the diaphragm. Alterations of intrathoracic tension thus induced may suffice to permit healing. If this fails to produce necessary improvement in a month or two, then ribs may be removed, a few at a time from below upward, or from above downward as seems best, with sufficient intervals between operations to determine when enough have been resected. Resections should be radical, i. e., extend from behind the angles forward to include some of the costal cartilages. This produces the greatest effect with each resection and helps to limit the number of ribs it is necessary to remove. The total incapacity from diminished external respiration may thus be limited to necessity; deformity is restricted and the more easily covered. More significant still, the operative mortality is virtually abolished. The operative burdens are limited, and the patients are well prepared to sustain them. They have already been provided with blood and have become accustomed to altered intrathoracic tension from the preceding paralysis of the diaphragm.

*2. Eradication of Irreparable Lesions Interfering with Recovery.*—A considerable number of patients are able to achieve healing of all but a few larger lesions, usually a cavity or a cluster of cavities, confined to one lobe, frequently the upper lobe. They are harassed by coughing, raise considerable sputum containing many organisms and are laid in a state of chronic invalidism until their defense weakens. They succumb frequently to a pneumonic extension of the process. Lobectomy is indicated and is feasible if performed with a cautery as introduced by Graham. Several patients have been advised to accept the risks of this operation. None has accepted.

#### OBSERVATIONS

A series of 100 patients have been treated in conformity with the plan outlined in the foregoing during the last two years in cooperation with the staff at Muirdale Sanatorium for Tuberculosis, an institution conducted by Milwaukee County. The patients have not been grouped

It is to avoid the necessity of these undesirable measures that the following procedure is proposed. The operation is not presented as a new or an original one, but is being drawn to the attention of thoracic surgeons as a valuable adjunct to the routine posterior thoracoplasties, to be used promptly as an additional stage in the operation in the cases in which incomplete collapse is secured. It consists in the removal of further sections of the upper ribs through an axillary incision.

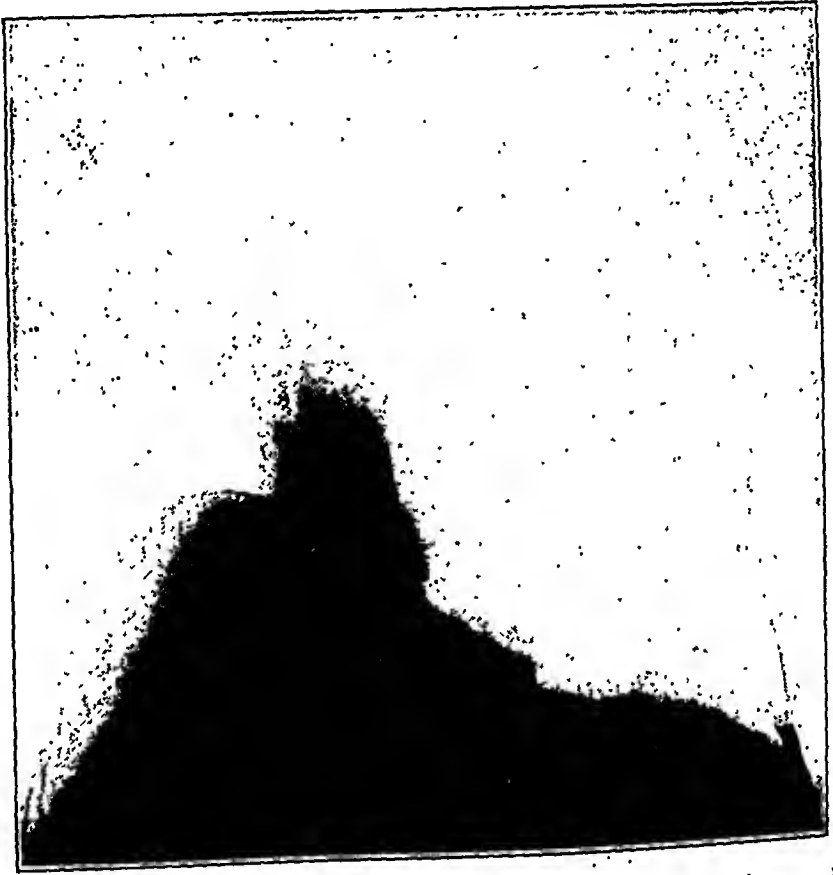


Fig. 3.—W. J. M. three weeks after figure 2 was taken, showing an increase in the size of the cavity. This was accompanied by an increase in sputum.

#### PROCEDURE

The patient lies on the back with the arm extended above the head. An incision is made in the anterior axillary line, starting at the tendinous portion of the pectoralis major and extending downward to the sixth or seventh rib. Skin and subcutaneous fat are cut through and as no muscles, large vessels or nerves are encountered, there is little bleeding, and the ribs are promptly exposed in a line posterior to the origins of the pectorals and anterior to the digitations of the serratus magnus. Beginning with the fourth rib, stripping with a periosteal elevator is at once begun, and the rib is bared forward under the pectoral to the cartilage, and backward under the serratus attachment all the way to the cut end left by the posterior thoracoplasty. The rib is removed in its entire length and the process is repeated with the third, fifth, sixth and probably the seventh, depending on the location and size of the cavity. The second rib is somewhat more

there is need for paraffined tubes and that they should be filled rapidly so that they may be emptied more deliberately and the transfusion terminated if signs of distress appear. Transfusions have not provoked hemorrhages in these patients. On the contrary, they replace serious losses of blood and may contribute to a cessation of dangerous bleeding.

*Induced Paralysis of the Diaphragm and Phrenicophraxia.*—Crushing the nerves conducting motor impulses to the diaphragm has been performed on eighty-five patients (seventy-eight in this series). The operative dangers are those incidental to infection, which are negligible. Those due to injuring other structures are avoidable. There is one postoperative danger. A measure of contralateral emphysema is produced as a rule by induced paralysis of the diaphragm. A superficial lesion of the supposedly sound or less involved lung can be ruptured and lead to a spontaneous pneumothorax which, if unrecognized and uncontrolled by aspiration, may lead to death. One such fatality has been noted; another was avoided by removing the air. Diagnosis of pneumothorax with a fluoroscope is easy and certain if the physical signs are confusing.

The dangers of subsequent hemorrhage are reduced. A few patients have raised blood streaked sputum some days after operation; one died from a single profuse hemorrhage from a bronchial artery on the third day before help could be given. Probably the destruction of the arterial wall was little influenced by the procedure. One patient in whom continued losses of pulmonary arterial blood threatened life did not bleed after phrenicophraxia. Another, lethally exsanguinated from repeated bronchial arterial hemorrhages received a blood transfusion and the nerve was blocked. He bled again that night; he was given another transfusion, and the bleeding ceased.

*Exeresis.*—The nerve has been withdrawn from the chests of eighteen patients. Twice withdrawal was incomplete and a phrenicotomy was performed. Twice the thoracic duct was torn and ligated without any noticeable handicap.

*Effects on the Diaphragm Noted with the Fluoroscope.*—Since experience has shown the importance of obtaining relatively complete relaxation, particularly that which leads to a paradox (the affected side rising during inspiration), and has taught how to find accessory branches, the majority of the operations performed have been satisfactorily effective. Exeresis failed to produce complete paralysis in only one patient. According to the amount of crushing employed, blocking can be made to last from two to five months. Degeneration of muscle is well advanced in six weeks, but apparently is recoverable up to six months. One patient thus far is known to have a permanent block when a temporary block was expected.



a chance to form new solid bone, has been most encouraging. One successful case is shown in figures 1 to 4. In other cases, in which the axillary operation was not attempted for six months or a year after thoracoplasty, the resulting compression was much less and the benefit derived correspondingly slight.

It is my intention to use this procedure in the future in those cases in which inadequate collapse is secured as soon after the thoracoplasty as the patient is in condition for a further operation. I feel sure that I shall have a smaller number of discouraged patients coming back several months later asking for further relief.

fusion without nerve block, of nerve block without transfusion, of nerve block and transfusion, and of costectomy with control observations on patients with similar conditions treated differently. Hence, there are sufficient grounds on which to base judgments.

Patients in group I were subjected to nerve block on the more affected side. Some of the operations were performed reluctantly because the patients requested them. A few of the patients improved unexpectedly. The question arises as to whether such patients as improved might have been served better if both sides had been paralyzed, when activity persisted in the contralateral lung, or if thoracoplasty had been performed on the side first treated when the lesions in the other lung were inactive or became inactive.

The patients in group II are those accepted as needing immediate thoracoplasty. Nerve block obviated the need for operation in a number of them, and reduced the extent and risks of operation required in the others. Determination to avoid unwarranted radicalism has sometimes delayed operation too long. It is difficult to estimate the peak of improvement. When this has been reached, resections should be begun. Unfortunately, some patients, on account of the improvement, refuse to consent to further intervention until it is too late to obtain benefit from operation.

The treatment of patients in groups III and IV is even more perplexing. Hesitation to have a thoracoplasty performed, with its inevitable permanent disability and deformity, permits some to progress into the preceding categories. Cessation of progress toward recovery, if it can be recognized, is the indication to proceed so that the number of ribs necessary to resect can be restricted.

Patients in group V present the gravest problems. A goodly proportion will recover with the usual hygienic measures—some promptly, others slowly; in the remainder, the disease will progress. It is impossible as yet to recognize the differences in susceptibility at the onset or soon after. Few recover in less than three months. Future observations will determine whether it is advisable to employ phrenemphraxis almost as a routine. If it is true that it is virtually without danger, is harmless and certain to raise pleuropulmonary resistance, defense and repair, its employment is justified as prophylaxis against progress of the disease and also against retarded recovery.

It should be recognized that no method suggested here is considered the best treatment. Each in its place is regarded as a useful adjunct to other measures that together comprise the most favorable treatment for each patient. Advocacy of nerve blocking is based on the natural responses which are favorably influenced and justified by comparison of the progress of patients subjected to it with that of patients otherwise receiving identical treatment in the same environment.

collapsing the normal upper portion of the lung, a complete resection of the whole length of the lower ribs is necessary, and resection of the fourth and often of the third rib must be included in order to prevent their suspending effect on the lower part of the wall of the chest.

Experience has shown that the operation cannot be performed safely in one stage in the presence of a large amount of sputum on account of the danger of pus retention and pneumonia; and because of the shock produced by so extensive an operation in a debilitated patient. A



Fig. 1.—A girl, aged 11 years, who had coughed and raised large amounts of sputum since an attack of pneumonia three years before; there is an absence of any abnormal lung markings, except a few linear streaks covered by the cardiac shadow.

several stage operation is necessary, graded to the patient's particular condition.

In 1923 I read a paper before this association reviewing the literature on the results of various surgical methods in the treatment of bronchiectasis, and included the case reports of seven patients on whom I had performed a graded extrapleural thoracoplasty without mortality and

## ABSTRACT OF DISCUSSION

DR. EDWARD ARCHIBALD, Montreal: It is interesting to observe the particular application of Cloetta's experiment with regard to the circulation of blood through the lung in conditions of compression of the lung. The question arises as to just how far this is obtained by the temporary paralysis of the phrenic nerve. Without doubt, phrenicotomy is a definite influence, but I had not thought of it before. It never occurred to me that that would be sufficient to make Cloetta's experiments applicable, at any rate, in a large measure. Nevertheless, the idea is novel, and the explanation of the good effects of phrenicotomy is novel. I welcome the presentation of a group of patients treated in this fashion along physiologic and scientific lines. It seems to me that it gives us a new vista and puts us a decided step in advance. The effort to get away from operations is always welcome to me. I think anybody who operates much on tuberculous patients realizes that a major operation on them is always a risk. Obviously, this effort to postpone operation, to limit it to more carefully selected cases, is one that we should consider carefully. I imagine that possibly in the present wave of enthusiasm thoracoplasty is being done, not infrequently, in cases in which it is decidedly unsuitable. The only question I should like to ask Dr. Yates is with regard to the incipient but active cases. I presume that these, which number only three, would lie in the class of apical tuberculosis. How far does a phrenicotomy on that side affect the activity at the apex? Of course, if it is a widespread activity through that lung, we could expect more from phrenicotomy. We know, at least it has been said, that phrenicotomy, even removed by the whole length of the thorax from the apical lesion, does affect the apical lesion in a sense. In any case, clinical improvement has followed phrenicotomy in more advanced lesions when the bulk of the lesion has been in the upper fourth of the lung. A patient with an early, active, incipient case hitherto has been given the ordinary hygienic treatment. Would these patients have improved in any case under ordinary hygienic conditions?

DR. A. V. S. LAMBERT, New York: This case should make us all think. It is a definite, conscientious effort to obviate the necessity for surgical intervention in cases in which the patients apparently are not doing well, and instead to use surgical measures on simple roentgen-ray examination. As Dr. Yates has stated, much more stress should be laid on the two elements of improving the quality and increasing the quantity of blood than on the elimination of the action of the phrenic nerve. To build up the resistance of these patients by transfusions is better than a simple division of the phrenic nerve. Many of us, I think, have been disappointed in the results from the simple division of the phrenic nerve; and there are no such statistics of good results from this procedure as there are from the use of transfusion. Therefore, the statistics Dr. Yates gives must be due to increasing the quantity and improving the quality of the blood. Since Dr. Yates had time only to sketch a description of transfusions, we have not been told how many, how often and what sort of blood examinations are necessary, how to determine when a transfusion should be made, and how much blood should be transfused. I am not so much interested in whether a phrenicotomy was or was not performed. That is the smallest part of the problem. Dr. Yates has done a piece of work better than any one else has done it. The two elements he has added are the quality and the quantity of blood.

DR. HOWARD LILIENTHAL, New York: I agree with everything that Dr Lambert has said except as to the phrenic nerve operation. I think that this operation is important. Any of you who have examined by fluoroscope patients with even tiny incipient apical lesions and have noted the striking fixation of the diaphragm on that side, must believe that the action of the diaphragm has something to

operation. Short abstracts of the former and more detailed reports of the latter follow:

#### CASES PREVIOUSLY REPORTED

CASE 1.—A boy, aged 19, had a postempyema bronchiectasis of about two years' duration. The sputum averaged from 240 to 500 cc. in twenty-four hours. The third to the eleventh ribs were excised in five stages. He gained weight and strength immediately after operation, and the sputum dropped to 30 cc. in twenty-



Fig. 3.—Simple cylindrical bronchiectasis of the right middle lobe.

four hours. During three years following the operation, there were intervals when he was practically symptom-free, but for the most part he continued to raise from 60 to 150 cc. of sputum in twenty-four hours.

CASE 2.—A man, aged 28, had had symptoms of bronchiectasis from infancy without known etiology. The sputum averaged from 500 to 1,000 cc. in twenty-four hours. The fourth to the tenth ribs were excised in three stages. The sputum decreased to from 30 to 90 cc. soon after the operation, and has averaged 60 cc. in twenty-four hours during nearly six years afterward. The patient is in the best of health, and is steadily employed at hard manual labor.

with lessened cardiac effort. These factors provide for repair of lesions, and for conserving the latent energy of the right side of the heart, on which recovery so often depends.

It should be remembered in reading the records of Muirdale Sanatorium for Tuberculosis that these patients were given the best care the management of the institution provides and that operations are merely adjuncts to treatment. Moreover, the patients subjected to operation had been under observation for weeks, months, some for years, in the same environment. Their condition is recorded as improved only if all observations, including blood examinations, sedimentation rates, physical examinations, vital capacity determinations, roentgenograms and fluoroscopic readings, are confirmatory. Their progress is also compared with that of other patients similarly affected but not subjected to operation. The progress compares favorably, but there is not as yet enough evidence to warrant any more definite statement.

There is general misapprehension as to the value of exposure to direct sunshine as a help to patients in combating pulmonary tuberculosis. It should be recalled that ingesta and sunshine are the sources of energy. If patients are overexposed to sunshine, their metabolism is hastened, and they are injured because of the increased consumption of fuel to provide for energy production. They must be treated wisely and not too well. Dr. Kassowitz, who controls this work at Muirdale, has studied under Rollier, and his careful methods have been remarkably successful.

Dr. Lambert asked for indications for transfusion. They are reductions in erythroblasts and in hemoglobin, reductions in the actual number of lymphocytes, distortion of proportions and numbers of leukocytes, and particularly hastened sedimentation. All have noted that the blood conditions become less favorable as patients are losing ground and become more favorable as they improve. We have observed the other aspect: If the blood is improved by transfusions, the patients likewise improve if they have not lost their capacity to recuperate. There is a widespread belief that transfusions are of little value for patients suffering from pulmonary tuberculosis. The reasons are that citrated blood has been employed instead of unmodified blood and that transfusions have not been performed repeatedly and frequently.

Dr. Lilienthal was good enough to give our efforts commendation because methods cooperating with nature's responses were of necessity the most efficacious. If anything has been accomplished, it is attributable to attempts to imitate the natural reactions of man and divers animals which confer the greatest defense to pleuropulmonary structures.

Dr. Lockwood's question may be answered. Numerous roentgenograms shown today illustrated the high position of a paralyzed diaphragm. The high position is produced by the combined actions of intrapleural negative pressure and of intra-abdominal positive pressure on an atonic diaphragm. If the amount of intra-abdominal pressure were materially increased, as after the repair of an enormous ventral hernia, the greater upward displacement of the diaphragm could so alter intrathoracic pressures as to embarrass the heart, already somewhat incompetent. One would judge that the increase in intra-abdominal capacity consequent on induced paralysis of the diaphragm would be too little to be effective, and the dangers might be considered prohibitive. Rather might it be wiser to increase the size of the belly cavity by causing relaxation of the abdominal walls induced by incisions, as advocated by Crile.

actinomycosis. He died of general asthenia a month later. (This was probably a case of actinomycotic infection of the lung following the onset of pulmonary symptoms after appendectomy.)

CASE 6.—A girl, aged 18, had bronchiectasis of nine years' duration following pneumonia. The sputum averaged from 360 to 480 cc. in twenty-four hours. The thoracoplasty was not completed on account of the pneumonia after the fourth stage. The cough and the sputum were not affected. A year later, the median segments of the sixth to the tenth ribs were removed. The sputum then diminished to about half that before thoracoplasty and the general condition was improved. Two and a half years after this, a partial cautery lobectomy was performed. Since this operation the sputum has averaged about 60 cc. in twenty-four hours. The patient has gained 15 pounds (6.8 Kg.) in weight and is in good general condition.

CASE 7.—A frail, anemic woman, aged 22, had had frequent hemoptysis in early childhood. She had raised purulent sputum which had increased in amount since she was 10 years of age until it was 240 cc. in twenty-four hours. Following a seven stage excision of the second to the eleventh ribs, the cough and sputum almost disappeared. At intervals she had no symptoms and the sputum never amounted to more than 30 cc. in a day. She gained in weight from 91 to 115 pounds (41.3 to 52.1 Kg.). This improvement has persisted, except for a few remissions, when the sputum increased to 60 cc. in a day. She has done all her housework unassisted.

CASE 8.—*History.*—A man, aged 19, a student, presented himself at the Mayo Clinic, Jan. 10, 1923, complaining of cough with purulent sputum. When 8 months old he was said to have "swallowed" a head of wheat which almost strangled him. He had had bronchiopneumonia shortly afterward, for which he had been treated at the Mayo Clinic. He had had a cough since, with a gradually increasing amount of sputum, at times blood streaked. Following tonsillectomy nine months before admission, the amount of sputum increased to from 240 to 300 cc. in twenty-four hours.

*Examination.*—The patient was in a good general condition. He had several carious teeth. The cervical and axillary glands were enlarged. There were loud bubbling râles at the right base. The blood pressure was 120 systolic, 80 diastolic; the hemoglobin content was 80 per cent; leukocytes totaled 9,200. No tuberculosis bacilli were found in the sputum. The urine was normal. The roentgenogram showed an extensive bronchiectasis at the right lower lobe and an old tuberculous process at the left upper lobe.

*Operation and Course.*—An extrapleural collapse of the right side of the thorax was effected by a seven stage operation, with removal of practically the whole length of the fourth to the eleventh ribs, inclusive. The posterior segments were first resected through a paravertebral incision in three stages, and the nerve trunks were injected close to the transverse process of the corresponding vertebra with 95 per cent alcohol solution. The anterior segments were next resected from below upward in two stages through a parasternal incision, the lower lateral segments through an incision parallel to and over the eighth rib, and the upper lateral segments through a midaxillary incision. The average interval between the stages was two weeks.

The amount of sputum gradually decreased during the course of the collapse operations to from 60 to 90 cc. in twenty-four hours. He was then discharged in good general condition, May 11.



Fig. 1.—Chest of W. J. M. before thoracoplasty, showing enormous cavity involving practically the whole upper lobe on the right; fluid level from unraised sputum in the cavity. Phrenicotomy had already been performed, which accounts for the height of the right side of the diaphragm.



Fig. 2.—W. J. M. immediately after a complete posterior thoracoplasty; the cavity is reduced to a small triangular space.



1918. She had been in bed for one month and had remained weak and coughed all summer, but had raised no sputum. In the autumn, following an attack of influenza, she began to raise green, foul smelling sputum, which gradually increased to 120 cc. in twenty-four hours. In May, 1922, she was sent to a tuberculosis sanatorium, where she remained for five months. A diagnosis of pulmonary abscess was made, and pneumothorax collapse was instituted and continued until about a month before she came to the clinic.

*Examination.*—The weight was about normal, and the general condition seemed good. The fingers were clubbed, and the nails were watch-crystal in shape. The left side of the chest lagged on respiration and the characteristic evidence of pneumothorax collapse was present, except toward the base. Roentgen-ray examination showed the left lung collapsed from above to about the nipple line laterally. Hemoglobin content was 90 per cent; the white blood cells totaled 13,500. The serum showed a small amount of albumin; the sputum was negative for tuberculosis. A diagnosis of bronchiectasis was made.

*Treatment.*—A more complete pneumothorax collapse of the lung was attempted, 2,000 cc. of air being instilled in five sittings during a period of twenty days. At the last sitting, the water pressure registered between 0 and plus 4 after 200 cc. had been injected.

The sputum decreased to about 15 cc. in twenty-four hours during two weeks of observation. Another attempt at pneumothorax was therefore made, but the water pressure became plus 4 after 300 cc. of air was instilled, and the roentgen ray showed the lung to be adherent at the diaphragm, preventing further collapse.

A graded thoracoplasty was then performed in six stages, the whole length of the fourth to the eleventh ribs being resected. She complained little of pain following the operations and had no complications. The sputum averaged about 30 cc. at the time of her discharge from the hospital. A little more than a year later, she reported that she was in good general health and had gained considerably in weight, but was raising from 30 to 120 cc. of sputum in twenty-four hours. Later, she was reported to have died of acute poisoning.

**CASE 10.—History.**—A laboring man, aged 25, came to the Mayo Clinic, July 12, 1923, because of weakness and hemoptysis. In 1917, following a severe attack of influenza, he had had three attacks of hemoptysis, raising about a pint (473 cc.) of blood at each attack. Since then he had had a chronic cough, raising about 60 cc. of blood tinged sputum in twenty-four hours. In December, 1922, he had had another profuse hemorrhage and had had several since then, averaging in amount from 250 to 500 cc. He had been in bed since the last one, March 15, 1923.

*Examination.*—The patient appeared in fairly good general condition. The left side of the chest lagged on inspiration. The percussion note at the left base was impaired, with diminished fremitus, and fine crepitant râles were heard on inspiration. The hemoglobin content was 72 per cent, and the leukocyte count 7,000; the Kolmer test was negative. The sputum showed no tuberculosis bacilli. Urinalysis was negative. Roentgen-ray examination of the chest showed no abnormality. Fluoroscopic examination revealed no motion of the left side of the diaphragm. A diagnosis of unilateral bronchiectasis of the hemorrhagic type was made.

*Treatment.*—A six stage thoracoplasty was performed during a period of nine weeks, the whole length of the third to the eleventh ribs, inclusive, being resected. There were no postoperative complications and little pain.

During the next two years, the patient had three hemorrhages at intervals and the sputum, which fluctuated from 30 to 90 cc. in twenty-four hours, was occa-

difficult of approach, and it may not be possible to remove its entire remaining length. A good sized piece, however, 2 inches (5 cm.) or more long, can be excised. It is not necessary to cut the first rib if it has already been divided in the posterior operation. Following the subperiosteal removal of the ribs, the lung will be seen to sink in freely with each inspiration, as in the paravertebral operations. The wound is closed with one subcutaneous layer of catgut and the ordinary skin stitches. There are no muscle layers to suture. A rubber drain is brought out through a small stab wound in the posterior axillary line, as it gives much better drainage there than if inserted in the main incision. A large pad



Fig. 4.—W. J. M. after accessory operation in axilla, showing much more complete compression of the whole right lung and obliteration of the cavity.

of dressing is applied and held tightly in place by adhesive strips running from sternum to spine. The use of the new elastic adhesive plaster (elastikon) is greatly to be recommended as it gives a steady pressure on the wound.

#### COMMENT

There is surprisingly little shock following the operation; much less than with paravertebral thoracoplasty or anterior apicolysis. My patients have been able to leave the hospital within a week after operation.

The result in cases in which the operation is performed soon after posterior thoracoplasty, before the periosteum left in the back has had

from four to five attacks a day. In 1920, he had been treated at home for five months for "tuberculosis." The next year a change of climate had brought about some improvement in the general condition only. In the spring of 1922, he had begun to have fever and pleuritic pains, and had been in bed for four weeks. He had had two similar attacks since, each accompanied by marked weakness and loss of weight.

*Examination.*—The patient was undernourished and anemic; the breath was foul and the fingers were clubbed. The entire left side of the chest lagged on respiration. There was decreased fremitus at the left base posteriorly and sibilant and bubbling râles, but no dulness to percussion or other abnormality. Roentgen-ray examination showed infiltration of the lower left lobe. The sputum showed no tuberculosis bacilli. Urinalysis was negative; the hemoglobin content was 79 per cent; the white blood cells totaled 8,200, and the Kolmer test was negative. The diagnosis was bronchiectasis of the left base.

*Treatment.*—An extrapleural thoracoplasty was performed in six stages at intervals of about one week, the whole length of the third to the eleventh ribs, inclusive, being resected. The convalescence was entirely uneventful. The vital capacity on admission was 3,900 cc. At the time of discharge, it was 2,650 cc. The hemoglobin was 55 per cent, and the white blood cells totaled 13,000. He gained in weight and strength. The sputum averaged from 180 to 240 cc. in twenty-four hours, and has persisted at about this amount since.

CASE 12.—*History.*—A married woman, aged 28, came to the Mayo Clinic, Aug. 9, 1923, complaining of cough with sputum and weakness. The cough was said to have dated from birth, and the patient could not remember when she did not have it. It was present all the year around, but was worse in hot weather and had been gradually increasing, especially in the last three years. The sputum was always thick, purulent, and of foul taste and odor, averaging from 120 to 240 cc. in twenty-four hours. She never had had any hemorrhages. Bronchoscopy showed some pus coming from the left lower bronchus, but most of it came from the right.

*Examination.*—The patient was somewhat emaciated. The breath sounds were tubular in character, and there were a few râles at the right base. Roentgen-ray examination of the chest showed bronchiectasis at the right base and some changes on the left. A roentgenogram of the right antrum of Highmore and of the right frontal sinus was clouded. The systolic blood pressure was 110, the diastolic 68. Urinalysis showed a small amount of albumin and some pus cells. The hemoglobin content was 77 per cent; the white blood cells totaled 7,800, and the sputum was negative for tuberculosis and fusiform bacilli. The Kolmer test was negative. The diagnosis was bronchiectasis of the right base (congenital?).

*Treatment.*—Because of the question of bilateral involvement, a pneumothorax collapse was deemed advisable as a therapeutic test. The lung was completely collapsed by nine instillations of filtered air, each of from 300 to 400 cc., and in all totaling 3,400 cc. The intrapleural pressure at the initial instillation was from 5 to 7 cc. negative pressure. At the last refills, it fluctuated about zero. The roentgenogram showed complete collapse of the left lung.

During the next two weeks, the sputum was practically nil, and the patient stated that she felt better than at any time before in all her life. The only symptom was dyspnea on exertion.

Because this therapeutic test seemed to show a unilateral involvement and one amenable to collapse therapy, a thoracoplasty was advised. A seven stage thoracoplasty was performed, from the second to the eleventh ribs, inclusive, being

# UNCOMPLICATED UNILATERAL BRONCHIECTASIS

## LATE RESULTS OF EXTRAPLEURAL THORACOPLASTY

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By uncomplicated bronchiectasis is meant the characteristic changes of that disease in a portion of the bronchial tree without parenchymal abscess formation or pneumonitis as determined by the roentgenogram. A more or less uniform shadow may be due to a thickened pleura only, but until recently there has been no means of excluding abscess or pneumonitis on a clouded roentgenogram. The clinical picture of chronic paroxysmal cough with an abundance of purulent sputum, clubbed fingers and more or less general debility is characteristic of uncomplicated bronchiectasis. Recurrent attacks of fever with an associated rapid loss of weight and strength and increased amount of foul sputum is typical of bronchiectasis with involvement of the surrounding lung tissue, the exacerbations of symptoms marking an extension of the disease process. In doubtful cases, however, in my experience the roentgenogram has been the final criterion of uncomplicated bronchiectasis (figs. 1, 2 and 3).

Extensive bilateral bronchiectasis is obviously not amenable to surgical treatment. The differentiation between unilateral and bilateral involvement has been difficult and uncertain. It has rested largely on the roentgenogram and the presence or absence of certain physical conditions. The roentgenograms following the injection of iodized oil, 40 per cent, will probably not only enable us to determine the distribution but may also enable us to recognize types of the disease hitherto indeterminate. In the cases reported here this method was not yet available. In my case 12, the pneumothorax therapeutic test demonstrated the unilateral involvement, although the evidence from bronchoscopy pointed to bilateral involvement. Other cases were excluded as bilateral by the pneumothorax therapeutic test.

Graded extrapleural thoracoplasty implies a collapse of the wall of the chest in several operative stages. The simplest and most effective method for securing a maximum collapse is the paravertebral resection of the upper eleven ribs. The resulting longitudinal drop of the whole wall of the chest is the most important factor in this massive collapse. In pulmonary tuberculosis, in which the apex usually is first and chiefly involved, its collapse is absolutely essential. In bronchiectasis, on the other hand, the lower portion of the lung is almost always the only part diseased. In order to secure complete collapse of the base without

solution of chlorinated soda (Dakin's solution) being used. The cavity had a capacity of 1,500 cc. at this time, and the sputum averaged about 450 cc. in twenty-four hours. Ten days after drainage was instituted, a toxic arthritis with edema developed over the knees and the ankles, but this gradually subsided. A month after the onset of the empyema, the cavity measured 270 cc. in capacity. On January 25, the patient developed an acute attack of appendicitis, and an appendectomy was performed. The convalescence following this operation was uneventful.

On April 15, the empyema was 15 cc. in capacity. The sputum varied from 30 to 75 cc. in twenty-four hours, and the patient was in a good general condition, weighing 5 pounds (2.3 Kg.) more than on admission. A plastic operation was then performed, and the patient was dismissed on May 2. At this time, the sputum averaged from 60 to 90 cc. in twenty-four hours. She was advised to return in two or three months for the completion of the thoracoplasty.

On June 11, 1924, the patient wrote that she still raised from 60 to 75 cc., and that she had gained 7 pounds (3.2 Kg.) in weight. In June, 1925, she came for inspection. She had taught a country school all year, walking a mile to and from the school in all kinds of weather and building her own fires. She appeared well, and physical examination showed no involvement on the opposite side. In June, 1926, the patient wrote that she had finished another year of teaching. The sputum was from 45 to 60 cc. in a day; the weight averaged from 102 to 104 pounds (46.3 to 47.2 Kg.)

**CASE 14.—History.**—A married woman, aged 46, came to the Mayo Clinic, Oct. 30, 1923, because of a chronic cough with purulent sputum. She had a dorsolumbar scoliosis of pronounced grade which had begun when she was 11 years of age. Except for this she had been entirely well, had had three children and had always worked hard.

Eight years before admission she had had a postpneumonic empyema, which drained through a bronchus periodically for five years. A rib resection had then been done for drainage of the empyema cavity. She continued to cough and raise an average of about 250 cc. of foul, purulent sputum after the empyema cavity healed.

**Examination.**—The patient was a weak, poorly nourished woman, weighing 88 pounds (39.9 Kg.), 22 pounds (10 Kg.) under her normal weight. There was a marked scoliosis and kyphosis of the dorsal and lumbar spine, the concavity being toward the left. There were no abnormal physical conditions in the right side of the chest. Roentgen-ray examination showed the characteristic picture of a diffuse bronchiectasis process on the left without evidence of pleural thickening or increased density of lung parenchyma. The urine showed a moderate amount of albumin and the sediment a few pus cells. The hemoglobin content was 75 per cent; the white blood cells totaled 15,300, and the Wassermann reaction was negative. The diagnosis was bronchiectasis on the left.

**Treatment.**—A three stage thoracoplasty was performed under combined regional and ethylene analgesia, the whole length of the ninth, tenth and eleventh ribs being resected at the first stage, the sixth, seventh and eighth at the second stage, and the second, third, fourth and fifth at the third stage. It was necessary to resect the second rib in order to allow the lower angle of the scapula to lie flat against the collapsed chest wall. The ribs were extremely deformed, a sharp angle replacing the normal longitudinal curve, and the ribs were greatly thickened and triangular in cross section. The external surface was about 1 cm. in width, the upper and lower surfaces from 2.5 to 3 cm. in width.

with encouraging results in all cases. On the basis of this comparative study of operative mortality on the one hand and of relief of symptoms on the other, following the various methods of treatment, I expressed the opinion that this method would seem to commend itself to further consideration. I found that unfavorable opinions regarding thoracoplasty were based largely on a priori consideration, on a one-stage operation with high operative mortality or on the failure to get results



Fig. 2.—Same patient as shown in figure 1 taken after the injection of iodized oil, showing diffuse cylindrical bronchiectasis of both lower lobes.

after an incomplete collapse. It seems probable also that some of the unfavorable results were in cases of combined abscess and bronchiectasis.

One of the questions frequently raised in relation to extrapleural thoracoplasty in bronchiectasis is as to the permanence of any immediate improvement obtained. It may be of interest, therefore, to record the further progress in the seven cases already reported, and the results in a later series of seven others observed from two to three years after

There was a marked decrease in cough and sputum, gain in weight, and general improvement in all cases during the first four weeks following operation. In four, the sputum decreased from 200 to 500 cc. to 15 cc. or less in twenty-four hours; in three, from 500 to 1,000 cc., from 240 to 300 cc. and from 250 to 300 cc., respectively, to from 60 to 90 cc. in twenty-four hours.

All these patients were followed for three years after operation and all except two (cases 1 and 4) have been followed to date, or to within a few months of the present time. Three have died, one (case 10) from a fatal hemoptysis. This, it will be recalled, was his outstanding symptom throughout. One (case 5) died of actinomycosis of the chest wall ten months after operation. It seems probable that this was a case of actinomycotic bronchiectasis. The third (case 9) died from acute poisoning. She was in fairly good condition during the two years that elapsed between the operation and her death, but continued to raise about 60 cc. of sputum in twenty-four hours. Six have remained markedly improved in general condition and the sputum has been reduced to an average of from 60 to 90 cc. in twenty-four hours. Two of these six patients have occasional exacerbations of symptoms when the sputum reaches 25 per cent of that before operation. Five may be said to be practically cured from the standpoint of symptoms and general health. One of these five (case 2) raises consistently from 60 to 90 cc. of sputum (500 to 1,000 cc. before operation), but that is his only symptom. He works steadily and is in the best of health. Another (case 7) has an exacerbation of cough with sputum three or four times a year, incident to a "cold," when she raises about 30 cc. of sputum. The other three have no cough and sputum or other symptoms and are living normal active lives.

#### COMMENT

Extrapleural thoracoplasty for bronchiectasis has been generally condemned—in most instances on the basis of a few cases—as a dangerous and ineffective operation. Performed in a single stage and under general anesthesia, it is, indeed, a dangerous operation. If, however, it is performed in stages, the number of them depending on the condition of the patient, and under local or combined anesthesia, the operative mortality on the contrary should be low. In my experience, it has so far been nil. The operation has been called ineffective because a collapse of the diseased lung, it is stated, is impossible and because the pathologic process is not affected. In reply to these statements, it may be stated that a review of roentgenograms taken after the collapse is completed demonstrates in each instance, in my experience, as complete a collapse as is obtained in favorable cases of pulmonary tuberculosis, after paravertebral thoracoplasty, and that although the diseased bronchi

CASE 3.—A girl, aged 12, had a postinfluenza bronchiectasis of three years' duration. The sputum was foul, averaging 500 cc. in twenty-four hours. The fifth to the eleventh ribs were excised in four stages. Immediately after operation the sputum decreased to from 15 to 30 cc. in twenty-four hours, and the patient was no longer kept awake at night by cough. She gained 15 pounds (6.8 Kg.) in weight in two months. During the last four years she has remained consistently symptom-free, has gained 40 pounds (18.1 Kg.) in weight, has finished high school and has the appearance of good health.

CASE 4.—A woman, aged 32, had a posttonsillectomy bronchiectasis. The sputum varied from 120 to 500 cc. in twenty-four hours. The third to the eleventh



Fig. 4.—Bronchiectasis of the left lower lobe after the injection of iodized oil.

ribs were excised in five stages. A marked general improvement followed. She has had occasional attacks of pain in the chest since with an increase in the cough and sputum, but these have always been much less than before operation.

CASE 5.—In a boy, aged 14, the onset of cough and sputum followed an appendectomy, five years before thoracoplasty. The sputum was variable in amount, reaching 300 cc. in twenty-four hours. The third to the eleventh ribs were excised in five stages. There was marked immediate general improvement and decrease in the amount of sputum. Nine months after operation abscesses began to form in the soft tissues of the chest wall, the pus from which showed



turned off. Later there was a slight recurrence during the few weeks in the hospital, but finally all symptoms ceased.

Another patient, a boy, had been coughing and spitting foul pus for twelve years, ever since he had had whooping cough. He is now 18 years old. I had him treated bronchoscopically in the hope that Dr. Yankauer might help him by lavage. Immediately after the procedure there was a terrific reaction, with a temperature of  $104^{\circ}\text{F}$ . and a weak pulse. I thought that he would die. Still I determined to try again. I did not want to operate on him if it could be avoided. He was thin and a poor risk. The bronchoscope was used again, with the same result; then he said that he would have no more bronchoscopy. I should have said so, too, although I am an ardent advocate of bronchoscopy. I performed this operation in two stages. There was almost as prompt and good a result as in the case of the young woman. He coughs a little in the morning, raising less than 30 cc. of sputum which is not foul, although the discharge had been extremely putrid before. He is working. I have had other cases in which I have attempted this operation, some of them many years ago, and it was on the result of these early attempts that I expressed disapproval of the method. The procedures were unsuccessful before the posterior method came into use. I have had one patient, but her case was one of those in which Dr. Hedblom warns that the operation should not be performed. A girl, aged 9 years, on whom everything else had been tried unsuccessfully had a unilateral bronchiectasis and abscesses. I had opened the abscesses by pneumotomy and had pushed the pleura from the wall of the chest, hoping to get a certain amount of collapse without performing a complete thoracoplasty. It did no good. The girl improved for a time; but she came back frequently for treatment for exacerbations. I then performed a thoracoplasty, but it did not cure her. Dr. Hedblom probably would have predicted that it would not. Then I tried the cautery pneumonectomy; she died of hemorrhage a few days afterward. She had one hemorrhage that I was able to stop because I happened to be there and plugged the wound. Then at 4 a. m. a few days later, when I was not in the hospital, there was another hemorrhage and she quickly died. I have seen many hemorrhages in cases of suppurations of the lungs, and I would emphasize again that this is one of the reasons for operating in these cases. I am glad that Dr. Hedblom evidently thinks as I do.

DR. WILLY MEYER, New York: It has been interesting to hear the late results of thoracoplasty in bronchiectasis. I recall the time, some fifteen years ago, when I began this work, when I had two cases in which I saw signs of brain involvement, abscess with suppurative meningitis. The patients died. Death occurred from this cause in about 25 per cent of the suppurative lung cases. That seems rather high. Although the procedure in the cases of Dr. Hedblom and Dr. Lilienthal was excellent the branch of the pulmonary artery might first be ligated and then a thoracoplasty performed, because the tying of this artery also produces the carnification of the lung. Of course, bronchiectasis is principally a disease of the bronchial system; yet carnification of the lung tissue helps. I have used the operation in three cases; the three patients recovered. When the adherent lobes of the lung are separated, it is possible to infect the pleural cavity.

I like to recall my experience with a patient in whom there was improvement after I had tied this branch of the pulmonary artery. He was not willing to have the additional thoracoplasty done, and went to Georgia because of the higher altitude. He reported from time to time. I repeat that nothing else was done but the tying of the respective branch of the pulmonary artery. He was in a poor condition, unable to attend to business, but today he is completely cured. Perhaps the combination of surgical intervention with the proper altitude is desirable in these cases as it is in the treatment of tuberculous patients after extra-

He returned for observation, June 29. Examination showed a good collapse of the right lung, but Litten's sign was still present on the right. A right phrenic resection was performed on the third day, following which he was discharged from the hospital.

On August 1, he returned for examination. The cough was no longer paroxysmal as before. The sputum averaged 60 cc. in a day. Fluoroscopic examination showed immobility of the diaphragm in a relaxed position. The general condition was excellent.

On September 6, roentgen-ray examination showed a remarkable amount of rib regeneration in a position of partial expansion of the pleural cavity. The



Fig. 5.—Appearance of same patient as shown in figure 4, after the injection of iodized oil after a three-stage extrapleural thoracoplasty in which the full length of the third to the eleventh ribs inclusive were resected.

regenerated segments were excised through the old lateral incisions. There was an immediate collapse of the underlying lung. At the time of his discharge, he was gaining weight and the sputum averaged from 60 to 90 cc. The sputum has persisted at about this amount during the three years that have elapsed. The general condition has been good.

**CASE 9.—History.**—A girl, aged 20 years, came to the Mayo Clinic, May 23, 1923, complaining of purulent sputum and of weakness of four years' duration. The onset of symptoms dated from an attack of pneumonia in the spring of

# SURGICAL TREATMENT OF INTRATHORACIC TUMORS AND TUMORS OF THE CHEST WALL\*

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It is difficult to distinguish the various forms of tumor of the thorax and chest wall clinically. It is first important to differentiate benign and malignant tumors. In many instances, the clinical history and physical manifestations of the tumor suggest the type of growth, but histologic examination of the tissue must usually precede accurate diagnosis.

The malignant tumors may be considered in two groups: those that primarily involve the structure of the thorax and chest wall, and those that secondarily involve these structures either by continuity or by metastasis from a primary growth elsewhere in the body. In the latter group, carcinoma of the breast is probably the most common primary lesion. Carcinoma of the thyroid not uncommonly invades the anterior mediastinum and manubrium. However, the primary lesion may arise in any part of the body.

In this article, I have not included the metastatic malignant tumors or intrathoracic goiter. I shall review the cases of malignant and benign primary tumor of the thorax and chest wall in which I have operated during the last two years. There are sixteen cases in the series: eleven of them were cases of malignant tumor, two of which were intrathoracic; five were cases of benign tumor, none of which could be definitely differentiated clinically from malignant tumors.

The benign tumor is usually hard, fixed and smooth, and the malignant hard, fixed and irregular in outline. The regional lymph nodes were not enlarged in any case, not even in the cases of extensive malignant disease.

The chief complaint was tumor in eight of the cases of malignant tumor and in one case of benign tumor. It was pain in three cases of malignant tumor and in four cases of benign tumor (table 1). In three cases the patient thought the tumor was in the mammary tissue.

There is little of diagnostic value in the age, sex or site of the tumor (table 2). The more malignant tumors were in the youngest patients. The right side of the thorax was more commonly affected than the left. The benign cases occurred only in females, and in two instances the tumor was thought to be in the mammary tissue.

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\* From the Division of Surgery, Mayo Clinic.

sionally blood streaked. He reported that he was 8 pounds (3.6 Kg.) underweight, but that he was doing light work.

CASE 11.—*History*.—A man, aged 27, a bookkeeper, presented himself at the clinic, July 23, 1923, complaining of a chronic cough with a large amount of purulent sputum. In January, 1918, he had had influenza, which confined him to bed for two or three days, and he had not been well since. About six months



Fig. 6.—Same patient as shown in figures 4 and 5, showing paravertebral hooked incision extending below and anteriorly in the course of the ninth rib. The three stages of the operation were performed through the same incision.

after the attack of influenza, he had begun to raise large amounts of purulent sputum. At first he had had a feeling of being "clogged" in the left side of the chest under the sternum, which had caused him to cough. He would lean forward and bring up from 120 to 960 cc. of yellowish green pus. After the attacks of coughing had become more frequent, until recently

injury may have been overlooked or forgotten. Loss of weight and undue dyspnea were not of diagnostic importance. Some degree of dyspnea was present in five cases. The two intrathoracic malignant tumors caused dyspnea from pressure. In the other three cases the dyspnea seemed to be closely associated with pain in the tumor. The average duration of the malignant tumors was four months, and of the benign tumors seven months. Loss of weight was slight except in three cases of extensive, rapidly growing tumor.

In table 4 the cases have been grouped according to the type of operation performed and the result obtained. The result has not been tabulated if the operation had been performed less than six months previously. The technic and extent of the operative procedure must of necessity vary to meet the indications in each case. In order to

TABLE 4.—*Intrathoracic and Chest Wall Malignant Tumors*

Case	Age, Years	Pathologic Diagnosis	Intrathoracic Tumor	Tumor of Chest Wall	Radical Operation	Palliative Operation	Pleural Cavity Opened	Recurrence	Present Condition Good	Months Since Operation	Subsequent Death	Months After Operation
1	31	Fibromyxosarcoma.....	+	..	+	..	+	+	+	8	..	..
2	18	Osteofibrosarcoma.....	+	..	+	..	+	6 months	+	17	..	..
3	13	Osteogenic sarcoma.....	..	+	..	+	..	+	..	..	+	..
4	15	Malignant endothelioma....	..	+	..	..	+	+	..	..	+	..
5	3	Osteogenic sarcoma.....	..	+	..	+	..	+	..	12	..	..
6	58	Chondrosarcoma.....	..	+	..	..	..	+	..	18	..	..
7	54	Chondrosarcoma.....	..	+	+	..	..	+	..	14	..	..
8	42	Lymphosarcoma.....	..	+	+	..	..	+	..	11	..	..
9	45	Fibrosarcoma.....	..	+	+	..	..	+	..	..	..	..
10	46	Lymphosarcoma (myeloma type).....	..	+	+	..	+	+	+	15	..	..
11	29	Fibromyxosarcoma.....	..	+	..	+	+	Recent operation	+	..	..	..

\* Positive.

† Negative.

simplify the tabulation the term "radical operation" has been used when the complete removal of the tumor was attempted and "palliative operation" when only a portion of the tumor was removed. A more complete account of the operative procedure is given with each case history.

Ethylene under positive pressure was the anesthetic in all operations. Radiotherapy was instituted either at the time of operation or soon afterward in all cases of malignant tumor. The operative procedure or results in the benign cases is not tabulated, as an exploratory operation, with removal of tissue for diagnosis, was performed in all five cases without complication or operative mortality.

There were two cases of intrathoracic tumor; the tumor was radically removed by a one-stage operation in one case, and by a two-stage operation in the other. The pleural cavity was opened during the operation in both cases without serious complication at the time of

resected during a period of seven weeks. The patient had practically no pain following any of the resections, and was usually up in a wheel chair the day following operation. Following the fourth stage, a pleural effusion suddenly developed, and 1,200 cc. of fluid was aspirated; 1,800 cc. of more sterile effusion was aspirated at two later sittings. The severe dyspnea was relieved by these aspirations. The patient was dismissed from the hospital one week after the last stage operation. At this time, she coughed only occasionally, raising perhaps a teaspoonful of viscid material. The weight was 97 pounds (44 Kg.). The vital capacity was 3,737. Neurologic examination showed anesthesia of the distribution of the spinal nerves which had been injected on the side on which the operation was performed.

A few months after returning home, she had pneumonia in the uncollapsed lung, but recovered. The general condition since has been good. She has done all her own housework since the operation, and spends a great deal of time in the summer caring for her garden. About a year after the operation the patient wrote, "I still cough occasionally and raise some sputum, but nothing to speak of, and the sputum I raise now is altogether different from the sputum I used to raise. I wish you could see how well I use my right arm."

**CASE 13.—History.**—A woman, aged 20, a teacher, came to the Mayo Clinic, Nov. 20, 1923, because of cough with foul sputum, fever and pleural pain. The past history was of no significance. She had had a tonsillectomy at the age of 13, and the left turbinate had been removed and the left antrum drained three months before coming to the clinic.

At the age of 15 months, she had had a bronchopneumonia. She had had a high fever and had been extremely ill for ten days. The mother stated that from that time she had had a chronic cough, with purulent sputum, and that she would wheeze whenever she lay down. Following tonsillectomy, she had improved somewhat. The cough was caused especially by stooping. The sputum was purulent and greenish and there was about 250 cc. in twenty-four hours. The amount gradually increased. She stated that she always had from two-tenths to 1 degree of fever. Occasionally, she had twitchy pains in the left side. She complained also of shortness of breath on exertion and of early fatigue. She had had two acute attacks of pain in the right lower quadrant of the abdomen and much soreness in that region since.

**Examination.**—The patient was a frail looking girl, weighing 110 pounds (49.9 Kg.). The fingers were clubbed. At the left base of the chest from about 5 cm. below the angle of the scapula, there was dullness to percussion and absent breath sounds. Above this level the sounds were bronchovesicular, with increased vocal resonance. When the patient bent over, she raised 120 cc. of thick green, foul-smelling pus. The base was then resonant, and the breath sounds were bronchial in character. Roentgenograms showed slight bronchial thickening at the left base. There was tenderness to palpation over McBurney's point. Urinalysis was negative. The hemoglobin content was 75 per cent; the leukocyte count totaled 17,800, and the Wassermann reaction was negative. The sputum showed no tuberculosis or fusiform bacilli or spirillae. The diagnosis was left bronchiectasis.

**Treatment.**—Two stages of a graded thoracoplasty were performed at intervals of one week, 10 cm. of the fourth to the eleventh ribs posteriorly being resected. Following the second stage operation, a pleural effusion developed. One liter of blood stained fluid was aspirated on December 12; on the next day, 2 liters of turbid fluid, and on the next day, half a liter of semipurulent fluid were withdrawn. The fourth day the fluid was definitely purulent and catheter drainage and irrigation were instituted, first, sodium chloride solution and then surgical

small recurrent tumor was removed after six months. In three cases, death followed recurrence within six months after operation; all of these were cases of extensive malignant disease in children. Operative death did not occur.

#### REPORT OF CASES

CASE 1.—A woman, aged 31, was admitted to the Mayo Clinic, Feb. 3, 1926, with pain in the right arm and shoulder, which had commenced twenty-four years before and had been constant and severe for six months before admission. Since the age of 7 she had had occasional attacks of dull, aching pain in the

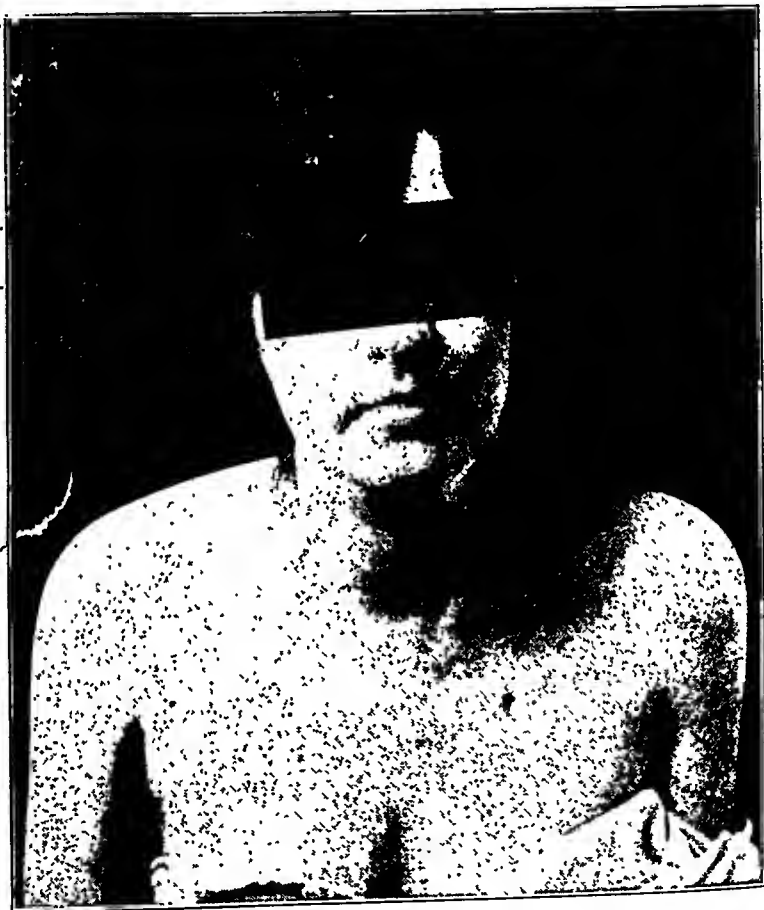


Fig. 1.—Dilatation of superficial veins of neck and upper part of chest; Horner's eye syndrome from pressure on right cervical sympathetic nerve.

right elbow and ulnar side of the right forearm, lasting intermittently from a few minutes to several days. The attacks were thought to be trivial, and were treated as rheumatism. One year before admission, the attacks had become more frequent and severe and of longer duration. Six months later, the pain had started as usual but had not subsided and had persisted constantly and with increasing severity after that time, so that opiates were required for relief. At the time of admission, the patient was taking from six to eight capsules in twenty-four hours. During the last two months before admission, the pain was severe, especially in the right shoulder, and was accompanied by pain, tingling and numbness down the ulnar side of the forearm and into the fifth, fourth

There were no postoperative complications. She suffered little pain after the operation except in the shoulder. The cough and sputum disappeared entirely following the last operation, and the general condition improved markedly. The deformity of the chest was much reduced. The patient has reported at intervals that she has had no cough or sputum, has gained in weight and is doing all her own housework and helping her husband with outside farm work. Her only complaint has been of shortness of breath in attempting to do heavy work.

#### SUMMARY OF CASES

Of the fourteen patients on whom a graded extrapleural thoracoplasty was performed, six were males and eight females. Five were under 20, the youngest being 12 years of age; seven were between 20 and 30, one was 32 and one, 46. In four the symptoms dated from infancy. The duration of symptoms in the others ranged from two to nine years. In one of the four cases that dated from infancy, there was a history of a foreign body and in one of an attack of pneumonia. In the other two, there was no known etiology. Possibly these were cases of congenital bronchiectasis. In the others, the symptoms followed influenza in three, pneumonia in three, empyema in two, appendectomy in one and tonsillectomy in one. The right base was involved in seven, the left base in seven. The maximum amount of sputum was under 200 cc. in one, between 200 and 500 cc. in ten, and between 500 and 1,000 cc. in two. In case 10, repeated profuse hemoptysis was the presenting symptom, between the attacks of which he had practically no cough or sputum.

There was a history of occasional attacks of slight fever with pleuritic pains in four, but none had had high fever, chills, loss of weight or other symptoms characteristic of abscess or pneumonia.

The roentgenogram in all cases except two showed the characteristic indefinitely outlined markings of bronchiectasis and nothing more. In one (case 10) the roentgenogram showed no abnormality, and in one (case 6) there was some uniform faint clouding characteristic of thickened pleura.

The thoracoplasty was performed in stages under combined regional and gas-oxygen analgesia with alcohol injection of the nerve trunks close to the spine to minimize the pain after operation. The whole length of the lower ribs, usually from the third to the eleventh, inclusive, was resected in multiple stages, the number of stages depending on the condition of the patient. In one (case 6) the thoracoplasty was not completed on account of a pneumonia following the fourth stage operation, and in one (case 13) on account of empyema after the second stage operation. A pleurisy with sterile effusion developed in two cases without interfering with the operative treatment. There were no other complications. There was no fatality after operation.



impaired, and there was numbness, 1+. The systolic blood pressure was 90 and the diastolic 78, practically the same in both arms. Raising the right arm caused diminution in the volume of the pulse and pain in the right hand. Dulness to percussion was found over the upper part of the right lung, with wheezing, bronchial breathing and increased vocal resonance and whispered sounds. The urine and blood were normal (fig. 1).

Roentgen-ray examination revealed a large circumscribed tumor in the right apex, extending to the third rib anteriorly and into the apex above the clavicle, more anteriorly than posteriorly, with destruction of a portion of the first and second ribs and displacement of the trachea to the left (fig. 2).



Fig. 3.—Fibromyxosarcoma of apex of right lung (intrathoracic); tumor exposed by resecting first and second ribs and cutting the clavicle.

Because the tumor was known to have been present for four years, and had probably existed for a much longer period, it was considered clinically as primarily benign, possibly fibroma, neurofibroma or dermoid cyst, but because of the marked increase of symptoms during the six months preceding admission the possibility of malignant degeneration was suggested. The clinical diagnosis was benign tumor, possibly with malignant degeneration, which involved the upper lobe and apex of the right lung in close proximity to the trachea, and secondary pressure neuritis on the brachial plexus (ulnar) and on the cervical sympathetic nerve, producing Horner's syndrome. Exploration was advised.

I performed the operation on February 9. Because the tumor presented more anteriorly than posteriorly, it seemed best to approach it through the

are not eradicated the operation has proved effective to the extent of markedly relieving cough and sputum in all cases, approximating a cure in many.

For those patients whose symptoms persist to any extent, a cautery lobectomy or a resection of the diseased lobe can be performed with relative ease of exposure and without the risk of tension pneumothorax from a retraction of the bronchial stump or from empyema. Sauerbruch reports lobectomy in six cases following thoracoplasty without mortality.

The operation of graded thoracoplasty, in my opinion, should be limited to undoubted cases of bronchiectasis. In cases in which the bronchiectasis is complicated by multiple or multilocular pulmonary abscess, the operation, in my experience, is relatively ineffective and the postoperative mortality is high. In a few cases in which abscess was recognized or suspected, improvement approximating a cure has resulted, but the operative mortality was more than 40 per cent.

The postmortem examination in all cases showed multiple or multilocular abscess in addition to the bronchiectasis. In my experience, the unclouded roentgenogram has been the only sure means of recognizing the borderline type of such cases.

Much renewed interest in the study and treatment of bronchiectasis will result from the introduction of iodized oil for its diagnosis. This method should be of the greatest value in making possible early diagnosis, in differentiating other pathologic conditions, and in the differentiation of bilateral involvement. In early unilateral, uncomplicated cases, pulmonary compression, pneumothorax collapse, phrenico-exeresis and in cases of insufficient relief by the simpler procedures, graded extrapleural thoracoplasty merits first consideration. For those cases in which there is not sufficient relief by these methods, pulmonary resection should be a relatively safe and effective operation.

#### ABSTRACT OF DISCUSSION

DR. HOWARD LILIENTHAL, New York: I wish to say that on theoretical grounds I was one of those who doubted the wisdom of thoracoplasty, but I have been convinced and now am on Dr. Hedblom's side. Dr. Packard of Saranac Lake referred to me a woman, aged 33, who had been coughing since she was 2 years old. In spite of that fact, however, the opposite lung was in good condition. She had been treated for tuberculosis for a long time. This seems to be one of those cases in which there are cavities as well as bronchiectatic conditions. These cavities were probably not active abscesses, but partly healed cavities whose walls were secreting less than the bronchiectasis below. The patient was not able to do any work. She was upraising large quantities of sputum; in fact, she did not know of a time when she did not spit and cough. I operated on her in two stages because she was in splendid condition, and she stood the ordeal well. Excellent collapse was secured. After the second stage, the patient stopped coughing. I have never seen anything like it. It was as if a faucet had been

sary to remove the pleura with the tumor. The size of the tumor necessitated partially breaking it in order to deliver it through the small opening (fig. 4). The muscles around the cut ends of the clavicle were sutured together and the ends of the bone, which were cut obliquely, were tied together with several strands of chromic catgut. These were placed in a groove designed for this purpose, and the wound was then closed. There was moderate shock, and the



Fig. 5.—Fibromyxosarcoma of apex of right lung; tumor 11 by 9 by 8 cm.

patient was given a blood transfusion immediately after the operation. The pathologic examination revealed degenerating fibromyxosarcoma (figs. 5 and 6).

The postoperative course was stormy for the first week. Collapse of the right lung, with bloody pleural effusion, followed the operation. The effusion was removed by aspiration three times, after which it was absorbed and the lung reexpanded. Owing to the removal of the first rib, and our inability to splint the arm because of the frequent dressings required, the clavicle did not heal by primary union but good fibrous union, and good function resulted. There was almost complete relief from the pain in the shoulder and arm.

pleural thoracoplasty. In advanced bronchiectasis this conservative type of operation has been performed with excellent results by a number of the members of this association. It is advisable to try it, particularly as it often is an introductory measure to the cautery excision or the resection of the respective lobes of the lung.

DR. STUART W. HARRINGTON, Rochester, Minn.: My experience with surgical pleural collapse of the lung by removing the bony framework has been of only two years' duration so that I cannot report late results. My results have been practically the same as those of Dr. Hedblom. My experience has been with seventeen cases, in which there has been one death from bronchiectatic abscess or abscess associated with bronchiectasis. The indications for surgical collapse should be established definitely. I have been cautious in the use of iodized oil in cases in which I planned surgical collapse, probably unjustified because of the possible retention of the oil. All patients are examined bronchoscopically to determine as nearly as possible whether the disease is confined to one lung and how extensive it is in that lung. I have usually performed the surgical collapse in three or four stages; recently I have been performing a much more extensive operation than formerly. I am now taking up the cartilage of the rib, leaving the cartilaginous angle from the sixth to the eleventh. Few patients have recurrences in which collapse was not complete in the lower lobe most extensively diseased. Hemorrhage is one of the chief indications for surgical collapse. The patient who died following the first stages was a poor surgical risk. She was sent away for three or four months. She returned with a recurrence of symptoms, having severe hemorrhage. I believe that death was caused by a cerebral hemorrhage due to pneumonia, caused by the retention of secretions. Results in the remaining sixteen cases have been satisfactory. I have a follow-up method for the patients. Every six months they fill out a questionnaire as to progress. Recent cases show results which may not be accurate because the time the cases have been followed has been too short. Of twenty-two patients whose cases I have followed for more than a year, all are well, and there have been no deaths in the group. Possibly some of the cases were of the minor abscess type, but practically all the patients have gone back to their usual life, and have been satisfied with the results. I have had two patients who have had slight bleeding following surgical collapse, but not of any serious degree. I agree with Dr. Hedblom in his views on the subject.

CASE 2.—A boy, aged 18 years, was admitted to the Mayo Clinic, April 27, 1925, because of a tumor on the left side of the chest wall. Six years previously he had fallen and injured the left side of the chest wall at about the posterior axillary line and thought that he had fractured a rib. He had experienced pain on deep breathing for about two weeks. Three years later, he had noticed a small flat tumor on one of the ribs in the region of the former injury. There was no increase in its size and no pain. One and one-half years before



Fig. 7.—Two and one-half months after removal of tumor from apex of right lung: separation of fragments of clavicle; good fibrous union; almost complete reexpansion of lung.

coming to the clinic, he had received a second injury to the left side of the chest wall while playing football; the attending physician said a rib was fractured. Strapping the left side of the chest had afforded relief from the pain, and he had been entirely well in two weeks. The small flat tumor was still present but did not increase in size. Six months later, he noticed that the tumor was a little larger and painful on slight trauma. The tumor was then thought to be a permanent callus around the end of the fractured rib. After that time the tumor gradually increased in size, more rapidly during the last six months, until at the time of his admittance to the clinic, it was about

The rapidity and duration of growth seems to be the most distinctive characteristic in this series. The benign tumors were practically all of slow growth. The malignant tumors were uniformly of more rapid growth (table 3). It was noted in three of the malignant cases that a small tumor followed an injury which occurred forty, twelve and six years previous to examination, respectively, and that the growth, after being dormant for many years, suddenly increased in size.

TABLE 1.—*Tumor of the Chest Wall*

Chief Complaint	Malignant	Benign
Tumor of chest wall on right.....	3	1
Tumor of chest wall on left.....	3	1
Tumor and pain of chest wall on right.....	1	2
Tumor of breast.....	1	2
Pain in right shoulder and arm.....	1	2
Pain in left shoulder.....	1	2
Total.....	11	5

TABLE 2.—*Age and Sex of Patient and Side Affected*

	Average Age, Years	Female	Male	Right Side of Chest	Left Side of Chest
Malignant.....	32+	6	5	7	4
Benign.....	35+	5	..	4	1
Total.....		11	5	11	5

TABLE 3.—*Symptoms and Course*

	Growth of Tumor				History									
	Slow	Rapid	Dormant; Growth Later	Pain	Pain Before Tumor	No Pain	Injury	No Injury	Loss of Weight	No Loss of Weight	Respiratory Symptoms	No Respiratory Symptoms	Average Dura- tion, Months	Cases
Malignant.....	4	3	4	4	2	7	4	7	6	5	5	6	4	11
Benign.....	4	1	..	2	..	3	1	4	2	2	1	4	7	5

Pain was not a constant or differentiating symptom of malignant and benign tumor, but when present with a rapidly growing tumor usually indicated a severe grade of malignancy. Pain was noted before the presence of the tumor in two of the malignant cases.

A history of previous injury at the site of the tumor was noted in four of the malignant cases and in one benign case. In three of the malignant cases the injury occurred years before and in one the tumor immediately followed the injury. This suggests the possibility of trauma as an etiologic factor in some of the malignant cases. There was no history of injury in seven cases, but it is possible that some previous

May 5, I removed the greater portion of the sixth, seventh, ninth and tenth ribs, sutured the visceral and parietal pleura around the tumor, resected the anterior one third of the eighth rib and cut the vertebral attachment, thus mobilizing the superficial portion of the tumor. Gauze was then packed around the tumor against the sutured pleural surfaces. May 18, I removed the tumor together with the attached pleura and a portion of the overlying skin (fig. 11).



Fig. 9.—Osteofibrosarcoma of the eighth rib at the left posterior axillary line. There was an injury at the site of the tumor at six years and at one and one-half years before examination.

There was a moderate amount of bleeding, which was controlled by a gauze pack. Moderate shock followed the operation, and physiologic sodium chloride solution was given intravenously. On the second day dyspnea increased and partial collapse of the lung was accompanied by a bloody pleural effusion, which had to be aspirated on two occasions. From the eighth day after operation the patient's condition improved gradually, and he had no further complications. The pleural effusion was gradually absorbed and the lung

operation. Pleural effusion and collapse of the lung on that side followed the operation in both cases. The pleural effusion was aspirated and absorption of the fluid followed with ultimate complete reexpansion of the lung. There was a small recurrent tumor in one case after six months, and it was removed. There has been no recurrence in the other case, and the patient is in good condition now, seventeen months after operation.

Radical operation was performed in six cases of tumor of the chest wall, with recurrence and death in one case five months after operation. In five cases there was no recurrence, and the patients are in good condition. The shortest length of time since operation is eleven months. Palliative operation was performed in two cases, in both of which death has subsequently occurred. Operative death did not occur. Three children under 15 years of age have died since operation.

The cases of malignant tumor were all classified pathologically as sarcoma, with one exception, which was endothelioma. The grading of the malignancy in the report of cases follows Broders' classification.

In the five benign cases the diagnosis was: atrophy of bone, tuberculous osteomyelitis, exostosis of bone, achondrosis of cartilage and areas of necrosis of cartilage.

#### SUMMARY OF CASES

In eleven of the sixteen cases of tumor of the chest, either intrathoracic or parietal, reported here, the tumor was malignant, and in five benign; in two cases of malignant tumor, it was intrathoracic.

The clinical differentiation of early malignant and benign tumors of the chest wall is difficult. When the diagnosis is doubtful, exploratory thoracotomy is indicated.

Early radical extirpation of malignant tumors, followed by radiotherapy instituted at the time of operation or immediately after operation, has given the best results. In cases of extensive disease, partial removal of the tumor, followed by the use of radium, did not seem to prolong the life of the patient or relieve the symptoms. Intrathoracic tumors at the apex of the lung may be exposed by cutting the clavicle. Large intrathoracic tumors of the lateral wall of the thorax may be removed by a two-stage operation, the first stage being directed at walling off the general pleural cavity by the formation of adhesions between the visceral and parietal pleura around the tumor.

Ethylene gas is a satisfactory type of anesthetic, and should be used with a positive pressure apparatus as the pleural cavity may be opened during any operation.

In six of the cases of malignant tumor, there has been no recurrence, and the patients have been well for from eleven to eighteen months after radical removal of the tumor. In one case of intrathoracic tumor, a



Every few days there was marked aching of the entire left side of the face, which lasted for hours and required sedatives for relief. The use of "medicine" brought some relief from the pain, but no other treatment was given. There had been a loss of 8 pounds (3.6 Kg.) in weight in two months. Dyspnea on exertion had become progressively worse.

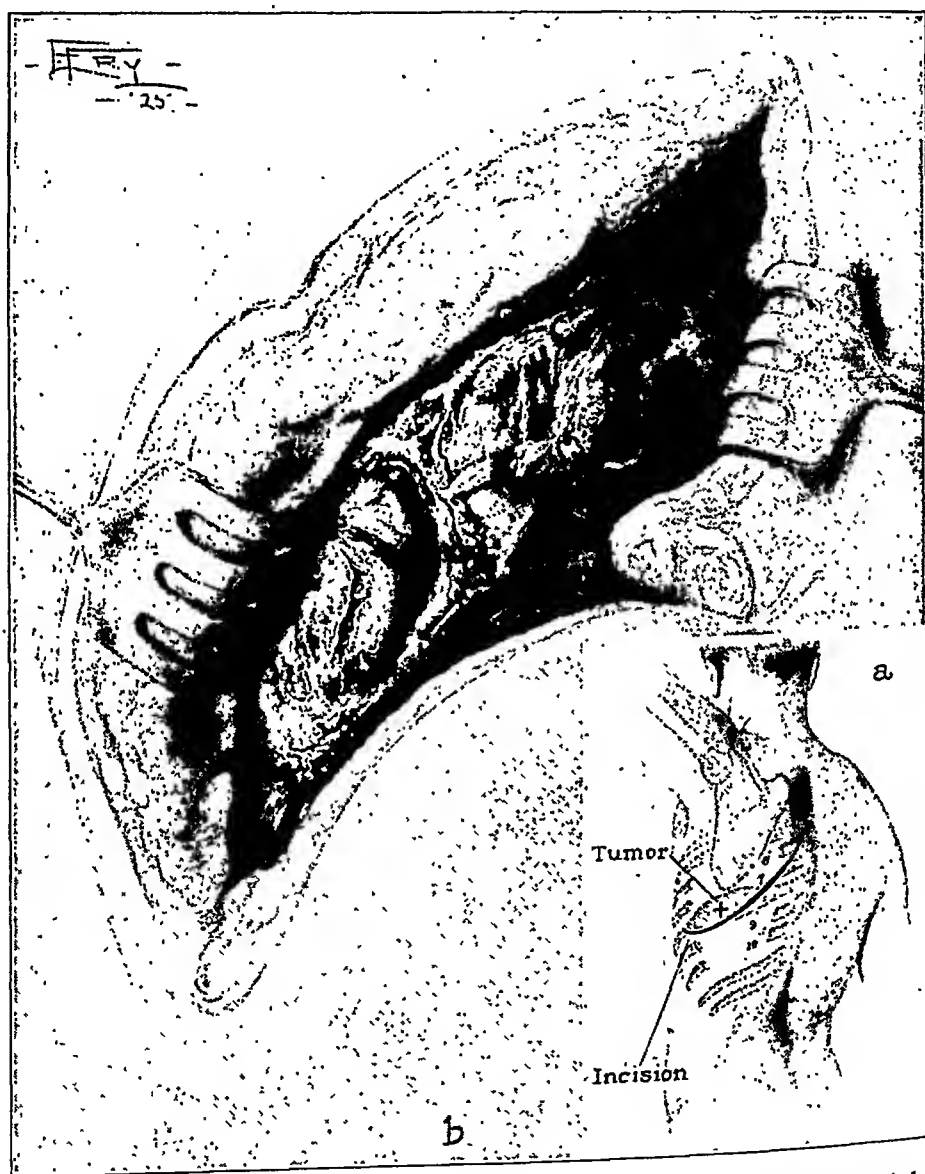


Fig. 11.—Osteofibrosarcoma on the left side of the chest wall and eighth rib (intrathoracic). Portions of the sixth, seventh, ninth and tenth ribs were removed, the pleura sutured and the anterior one-third of the eighth rib resected to mobilize the tumor.

The patient seemed to be undernourished. A tumor of the right side of the bony chest wall posteriorly involved the first and second ribs above and medial to the scapula. There was hyperesthesia of the left scapular region and marked tenderness in the left axilla. There was increased heat in the left arm and hand, and the nails of the left hand were slightly cyanotic. The pupil of the left eye was contracted, and there was ptosis of the lid (Horner's

and ulnar side of the third finger of the right hand. The right arm was never swollen, and the patient said she thought that the arm had become slightly smaller during the last year. She had lost 5 pounds (2.3 Kg.) in weight during the year. She had been subject to migraine headaches for many years. There were no respiratory symptoms other than undue dyspnea on exertion. Four years before admission, a general examination had been undertaken because of suspected anemia. The abnormal physical signs in the upper part of the right lung prompted roentgenographic investigation, and a tumor was found at the apex of the right lung which extended to the level of the second rib. The finding of

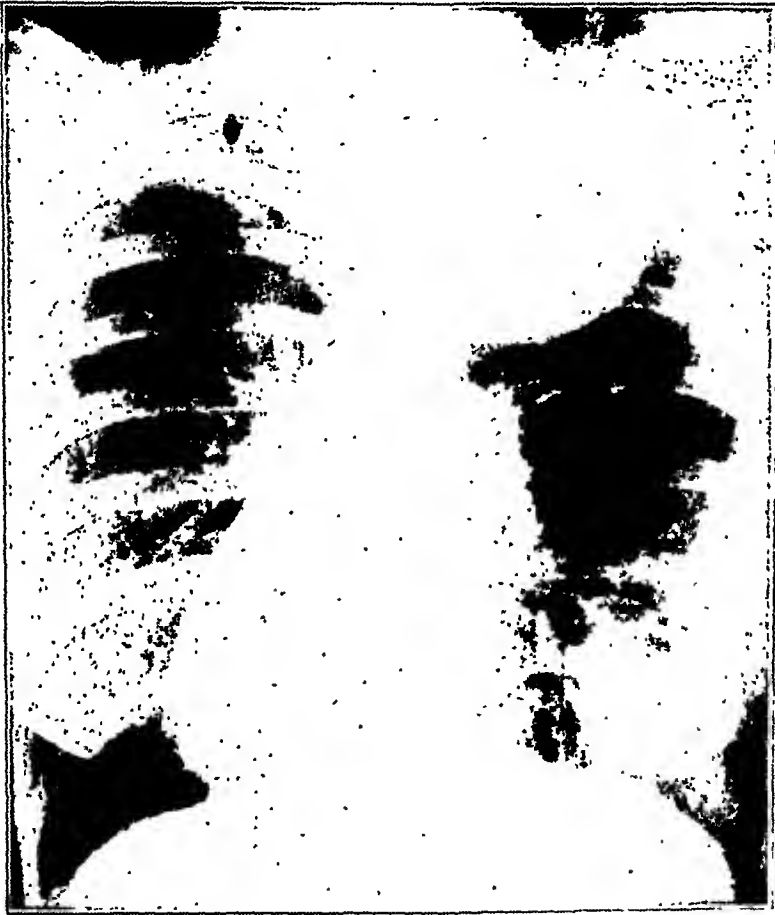


Fig. 2.—Circumscribed tumor of upper part of right lung, with partial destruction of the first and second ribs.

the tumor was accidental, and there was no association made between the attacks of pain described above and the presence of the tumor until three and one-half years later, when the pain became constant and severe. Intensive roentgen-ray treatment was instituted without relief of the symptoms or any appreciable decrease in the size of the tumor.

The patient was moderately developed and nourished, weighing 100 pounds (45.4 Kg.). The pupils were unequal, the right contracted, and there was ptosis of the right eyelid (Horner's eye syndrome). The superficial veins in the right side of the neck and upper part of the chest were moderately dilated. The right hand was smaller than the left (the forearm 2 cm. smaller), sensation was

returned home the fourteenth day following operation. A poor prognosis was given and there was only slight relief from the pain. The patient died May 7.

CASE 4.—Girl, aged 15 years, was admitted to the Mayo Clinic, Nov. 14, 1925, stating she had had good health until five months before, when she had first noticed pain in the posterior part of the chest wall on the right, just



Fig. 13.—Fifteen months after radical excision of osteofibrosarcoma on left side of chest wall and eighth rib; the patient was 12 pounds (5.4 Kg.) above normal weight.

below the shoulder blade, when lying in bed. Gradually the pain became more noticeable until its severity caused painful breathing; for the week previous to admission, she had been confined to bed. About three months before admission (two months after the onset of pain), a tumor was first noticed in the painful region. It grew rapidly and at the time of examination it was about 7 cm. long. A specimen of tissue removed two weeks previously was reported

anterior thoracic wall, and to complete the operation in one stage, if possible, so as not to interfere with the reexpansion of the lung. In two stage operations, the thickening of the pleura following the first stage of the operation often limits reexpansion. One incision was made from the base of the neck, over the juncture of the inner and middle thirds of the clavicle, to the second rib, and a second was made along the second rib from the sternum to the anterior axillary line. The pectoral muscles were severed. The second rib was found to be partially degenerated, and the anterior half was removed. The clavicle was then sawed through at the juncture of the inner and middle thirds and the first rib thus exposed. It was markedly degenerated, and the anterior half was

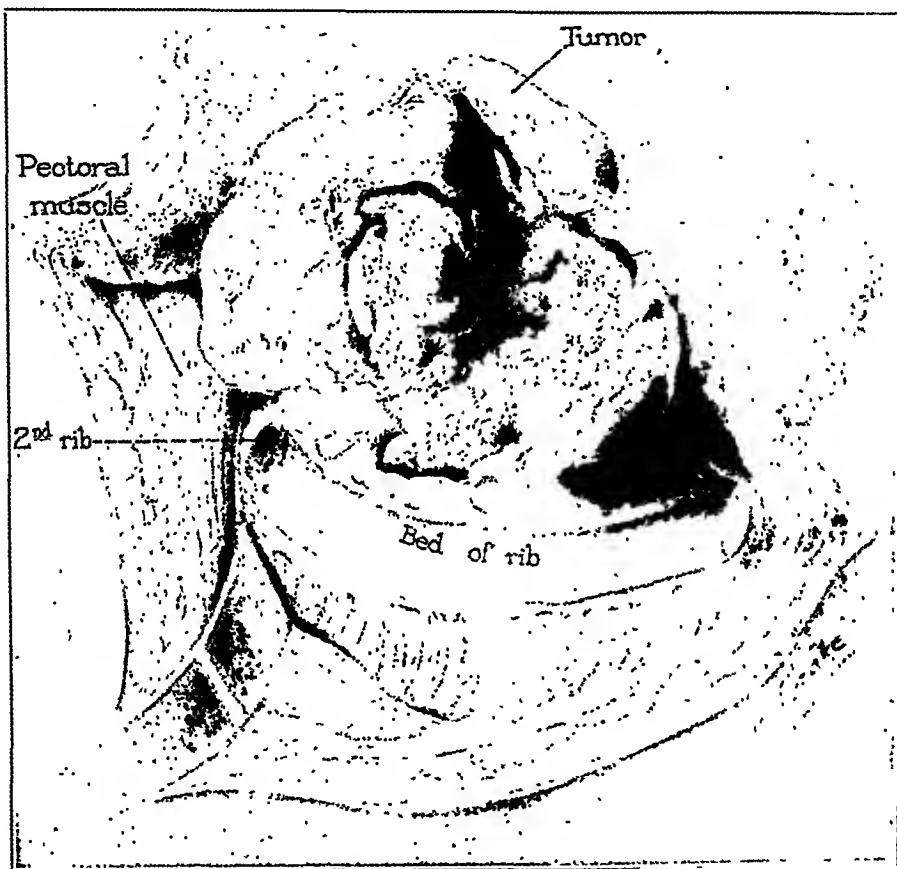


Fig. 4.—Fibromyxosarcoma of apex of right lung; removal of tumor by enucleation and maceration with finger.

removed. The subclavian vessels were pushed out of the field and protected by gauze sponges. Retraction of the two cut ends of the clavicle exposed the apex of the lung, and the tumor could be seen bulging through the second interspace to the apex of the thoracic cavity. Just above the first rib the tumor had crowded the lung tissue entirely out of the apex of the thoracic cavity and presented just beneath the parietal pleura. A small incision was made over the tumor, which was found to have a fairly well marked capsule, although at points it was adherent to the pleura (fig. 3). The pleura was easily separated on all sides except at the mesial portion, where the tumor was firmly attached to the vertebra by a pedicle about 2.5 cm. in diameter. It had to be torn from the vertebrate attachment, with a moderate amount of bleeding. It was neces-

Result: At the tumor had then reappeared. At the sixth week, she commenced moving the right arm. Little change was noted on examination of the presence of a tumor at the site of the previous operation in the region of the thorax. The hemoglobin was 44 per cent. The examination showed destruction of the eighth rib posteriorly on the right with pleuritic thickening at the right base.

At the operation, the tumor, radically removing the posterior half of the eighth rib, the intercostal muscles and a portion of the pleura. The pleura was closed. The left pleural cavity was not opened. The wound was packed with gauze. Radium was inserted when the gauze was removed forty-eight hours after the operation. The pathologic report was osteogenic sarcoma.

Convalescence was uneventful. The patient returned for radium treatment, September 1, and there was no local evidence of recurrence at this time. The hemoglobin was 38 per cent.

A letter from the child's parents stated that she had died, December 16, approximately nine months from the time the tumor was first noticed. She suffered a great deal of pain from about two weeks following the last radium treatment until death.

CASE 6.—A man, aged 58, was admitted to the Mayo Clinic, Aug. 27, 1925, because of a tumor of the right side of the chest wall. Forty years previously he had been kicked in the right side of the chest by a mule, and there had been a small tumor about 2.5 cm. in diameter at the site of the injury ever since. There was little growth until six months before his admission to the clinic, but after that it doubled in size. There was no pain, loss of weight or respiratory symptoms.

Results of the physical examination were essentially negative, except for a hard, irregular tumor, 7.5 by 10 cm. in size, which was firmly attached to the fourth rib on the right. Results of the laboratory examinations were practically negative. Roentgen-ray examination of the thorax showed a tumor involving the third and fourth ribs on the right with pleural thickening at the second, third and fourth interspaces. The diagnosis was malignant tumor of the right side of the chest wall, probably sarcoma.

September 3, I resected the tumor with about a third of the fourth rib and the surrounding tissue. The tumor was about 10 cm. in length and had caused complete destruction of about one-fourth of the fourth rib. The pathologic diagnosis was chondrosarcoma, grade 1.

Convalescence was uneventful, and radium treatment was given over the affected area. A letter from the patient's physician, May 4, 1926, eight months after the operation, stated that he had examined the patient and that there was no evidence of recurrence. He was doing manual labor every day.

CASE 7.—A man, aged 54, was admitted to the Mayo Clinic, Jan. 27, 1925, complaining chiefly of a tumor of the right side of the chest wall. Twelve years before admission injury of the right lower part of the chest wall from a fall had been followed by soreness and severe pain over the injured area. The patient was not certain whether the ribs had been fractured. The pain had subsided in about two weeks, and there had been no further trouble until two months before admission, when he noticed a burning sensation on the right side of the lower part of the chest at about the site of the injury twelve years before. The burning continued, and in a few weeks he noticed a small immovable mass which was connected with the right lower ribs. The mass gradually increased in size, but there was no pain, loss of weight or respiratory symptoms.

Six months after the operation, the patient returned for observation. She was in good health and had gained 9 pounds (4.1 Kg.) in weight. There was occasional pain in the right forearm and some limitation of the motion of the right arm, due to the fibrous union of the clavicle. There was no cough, fever, sputum, hemorrhage or undue dyspnea. Horner's syndrome persisted. The lymph nodes in the axillary and supraclavicular regions were normal. There was a small hard mass just below the clavicle on the outer border of the pectoralis major. On removal it was found to be a small recurrent tumor in the substance of the major pectoral muscle, measuring a little more than 1 cm. in diameter, and of the same type as the original tumor. Radium and roentgen-ray treatments were given.

In a reply to a questionnaire, sent Sept. 4, 1926, the patient stated that her general condition was satisfactory in every respect except for slight restriction of the motion of the right arm and some shortness of breath on moderate exertion. She had maintained the gain in weight (figs. 7 and 8).

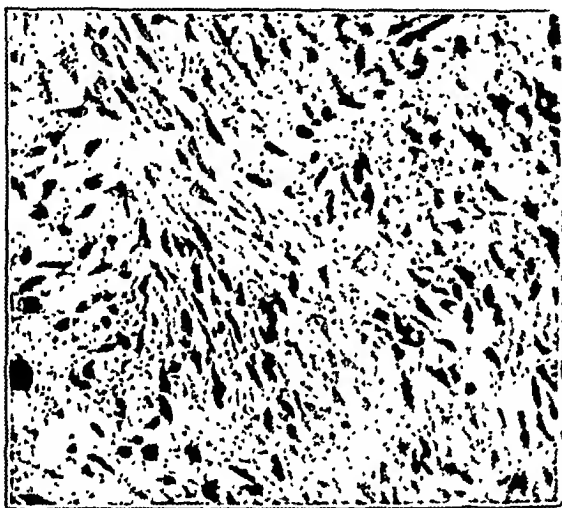


Fig. 6.—Degenerating fibromyxosarcoma;  $\times 150$ .

This case is of interest because of the rarity of operable tumors in this situation. From its point of attachment it would seem that this tumor had originated in the intervertebral disk of the first and second thoracic vertebrae, and from its apparent long duration one would conclude that it probably was at first a simple fibromyxoma, which had undergone malignant degeneration. This emphasizes the necessity of recognizing intrathoracic tumors early as the possible cause of subjective symptoms other than those of a respiratory nature, and of operating early when possible. I have not found any record of a similar case in which the approach was made by cutting the clavicle. The exposure was satisfactory in this case, and the resultant slight limitation of motion of the arm was of no practical importance. I do not believe that it should be considered a contraindication to this method of approach.

Results of physical examination were essentially negative except for a large tumor at the lower angle of the left scapula presenting at the axillary border, about 10 cm. in diameter; it moved with the scapula and had pushed the scapula upward and backward. There was moderate limitation of the motion of the left arm. There were a few small enlarged lymph nodes in the right axilla. Results of laboratory examinations were practically negative, as were also those of roentgen-ray examination of the thorax and scapula. The clinical diagnosis was tumor of the left scapula and chest wall, probably benign fibroma or possibly fibrosarcoma.

October 8, I removed a large tumor, measuring 12 by 9 by 5 cm., which extended beneath and along the vertebral border of the scapula and was attached to its ventral surface, as well as to the chest wall under the scapula. The tumor was encapsulated, and enucleated easily except at its two points of attachment. Pathologic examination disclosed fibrosarcoma in a fibroma.

Convalescence was uneventful. Intensive radium treatment was applied over the area affected. In a reply to a questionnaire of Sept. 4, 1926, the patient stated that his general health was excellent, that he carried on all his usual activities and that there was no limitation of the motion of the arm. He had gained 12 pounds (5.4 Kg.), and there was no evidence of recurrence of the tumor.

CASE 10.—A woman, aged 46, was admitted to the Mayo Clinic, June 23, 1925; two years previously the left breast had been removed for malignant disease. Four months before coming to the clinic, the patient had noticed a tumor in the right breast and this had increased gradually in size. There was no pain, loss of weight or respiratory symptoms, and no history of injury. There was a postoperative scar from removal of the left breast two years previously, without evidence of recurrence in the scar or regional lymph nodes. There was a hard mass beneath the lower medial quadrant of the right breast, which was fixed to the chest wall at the fifth rib. There was no enlargement of the axillary lymph nodes. Results of laboratory examinations were practically negative, as were those of roentgen-ray examination of the thorax. The clinical diagnosis was malignant tumor of the right wall of the chest, probably sarcoma or metastatic carcinoma.

July 2, I resected the tumor and about 7 cm. of the fifth rib and the surrounding tissue, including the cartilage and a portion of the sternum. The pleural cavity was not opened. The wound was packed with gauze and intensive radium treatment was given later. The pathologic diagnosis was lymphosarcoma, myeloma type. Convalescence was uneventful.

The patient returned for observation, November 24, and was in good general condition. There was no evidence of recurrence. In a reply to a questionnaire, sent Sept. 4, 1926, she stated that her health was good and that she was doing practically all her own work. She had gained 22 pounds (10 Kg.) in weight. She had some pain in the right side of the chest and spine when especially tired. There was no evidence of recurrence of the tumor.

CASE 11.—A woman, aged 29, was admitted to the Mayo Clinic, July 5, 1926, stating that five years before admission she had first noticed a small nodule in the posterior part of the chest wall on the right. There was no history of injury, soreness or pain. The tumor grew slowly for two years, and then began to enlarge rapidly and attained a diameter of 10 cm. in one and one-half years, at which time it first caused pain. The tumor was excised elsewhere one and one-half years before she came to the clinic. Two or three months





wall, and was not painful on pressure. Results of the laboratory examinations were practically negative, as were those of the roentgen-ray examination of the thorax. The clinical diagnosis was malignant tumor of the wall of the chest on the right.

July 21, I drained a tuberculous abscess under the right pectoral muscle which had originated in the chest wall, probably from the eighth to the ninth costal cartilage. Convalescence was uneventful.

In a reply to a questionnaire of Sept. 4, 1926, the patient stated that her general condition was good and that she was able to carry on most of her usual activities. There had been no loss of weight. She suffered more shortness of breath on exertion than normally.

CASE 14.—A woman, aged 29, was admitted to the clinic, Aug. 7, 1925, her chief complaint being pain and tumor in the right side of the chest. Six years previously, she had received a blow on the right side of the chest and since that time had experienced occasional pain. She had been struck again in the same place one year before admission and the pain had been more pronounced at that time. She had first noticed the tumor of the rib several months before admission. Pus had drained from the right breast periodically for the last three to six years. The lymph nodes under the right arm had been painful for the last six months, and there had been pain on motion of the right arm. The patient had many other irrelevant complaints. She had lost 5 pounds (2.3 Kg.) but had had no respiratory symptoms.

There was prominence of the third rib on the right with tenderness on pressure. Roentgen-ray examination of the thorax showed slight density at the right fourth intercostal space. The clinical diagnosis was old fracture of the fourth rib with callous formation. Conservative treatment was advised.

The patient returned, September 1, greatly worried about the tumor, stating that pain was severe and constant and that she feared malignancy. There had been no change in the character of the tumor, but the patient wished a positive diagnosis. Exploration was advised.

At operation, September 3, I found an old fracture of the third rib anteriorly with exostosis of the bone. The pathologic diagnosis was exostosis, probably old fracture. Convalescence was uneventful.

CASE 15.—A woman, aged 37, was admitted to the Mayo Clinic, Feb. 25, 1925, her chief complaint being tumor of the anterior chest wall. Five months before she came to the clinic she had first noticed a tumor of the third left costal cartilage. There was no history of injury or pain. The tumor increased in size slowly and the patient worried about malignancy. There was no loss of weight and no respiratory symptoms were noted.

There was a small tumor of the third rib at its juncture with the cartilage. Roentgen-ray examination of the thorax was negative. The clinical diagnosis was tumor of the left anterior portion of the chest wall, probably benign.

The patient returned, October 7, greatly worried because the tumor seemed to have increased in size and had become somewhat painful. Her general condition was unchanged, but she was nervous and worried. She had gained 10 pounds (4.5 Kg.).

October 8, I removed the cartilage and about 2.5 cm. of the third rib. The pathologic diagnosis was achondrosis of the costal cartilage. Convalescence was uneventful.

CASE 16.—A woman, aged 32, was admitted to the Mayo Clinic, Sept. 15, 1925, stating that seven years previously she had first noticed a lump in the right breast. It had increased in size slowly for six years and had been painful



skull and scapula. I myself when operating on these patients always add air-tight drainage of the pleural cavity for two or three days. It excludes worry in the first days after operation, as the often abundant secretion of the pleura and the parenchymatous bleeding from the resected ribs into the pleural cavity can be drained off by this method.

DR. CARL A. HEDBLUM, Chicago: The end-result following operation for sarcoma of the thorax is discouraging. The operation is worth while in the majority of cases because life is prolonged and the patient made more comfortable, but if one studies the end-results after a period of years, as in a series of 200 chest wall tumors that I reviewed some years ago, one is struck with the fact that practically without exception these patients die of sarcoma. One patient in the Mayo Clinic series lived six years and one was symptom-free after twelve years. Dr. Harrington's cases, with the one exception of the epithelioma, were all cases of sarcoma of some secondary type. The point I wish to make particularly is that a large proportion of the cases of sarcoma begin as nonmalignant tumors, particularly chondroma, and it is during this stage of the tumor that we can hope for a permanent cure if only we can get the family physician, who sees the patient first, to realize the importance of prompt treatment as soon as the tumor is recognized. Of course, a considerable proportion begin as sarcoma, and in such cases this argument does not apply. But I have seen chondroma and osteochondroma present from five to twenty years before the onset of symptoms indicating malignant changes. One other point as to differential diagnosis: When the tumor is small, it may be difficult to decide whether one is dealing with a neoplasm or with an unnatural bulge of a rib. I have had several such cases, and I have taken the attitude that it is better to perform exploratory operations for a simple abnormality of the rib than to miss a neoplasm in the early stage. I have found in some such cases that the appearance of a tumor was produced by a bulging, usually of the second or third rib at the costochondral junction, at which the rib would seem to have grown longer than the normal length and so have caused a bulge of the rib at that point. I have excised several such bulging ribs without any complications resulting.

I was much interested in Dr. Lilienthal's suggestion. In these cases of sarcoma anything that may seem promising is worth a trial, but I would plead especially for emphasis on the point that any tumor of the chest wall should be dealt with radically during the early stage. In that way, we will be able to remove growths before they have developed malignant changes.

DR. LEON T. LEWALD, New York: I wish that Dr. Harrington would give us further suggestions as to the differential diagnosis between benign and malignant tumors of the chest. Dr. Hedblom has emphasized exploration as one way of diagnosis. In one case which I saw, the posterior diagnosis of malignancy was not made until there was rib involvement. The man was 63 years old. He had had pain and cough for six months. The lesion was considered at first to be an encysted empyema until a negative puncture was made. The diagnosis of a malignant tumor was not suspected. At the time that Dr. Green and I saw him, after a number of exposures had been made producing roentgenograms with variations in density, we deliberately overexposed the film, and by thus penetrating the tumor mass and blotting out all lung detail, we were able to show definite rib involvement. The diagnosis was confirmed by operation. The tumor was an epithelioma and was inoperable. The patient died shortly afterward. Are there any criteria for the differential diagnosis between benign and malignant tumors growing slowly?

syndrome). There was no enlargement of the regional lymph nodes. The hemoglobin was 68 per cent; erythrocytes numbered 5,500,000 and leukocytes 10,100. The Wassermann and Pirquet tests were negative. Other laboratory studies were essentially negative. The long capillaries showed no dilatation in any of the loops; there was no stasis, and the flow was even and fast. There was no difference in the capillaries of the hands. The temperature of the skin at the shoulder on the left was 34.5, right, 33.3; above the elbow, left, 32.9, right, 32.3; below the elbow, left, 35.3, right, 33; on the back of hand, left, 36.4, and right, 33.9.

Ophthalmologic examination showed that vision was practically equal, and the ocular reflexes and visual fields normal; the fundus was normal, and Horner's syndrome was present on the left. Roentgen-ray examination of the thorax showed a tumor in the left side of the upper part of the chest wall, with extensive destruction of the first and second ribs posteriorly. The clinical diagnosis was malignant tumor of the upper region of the bony chest wall.

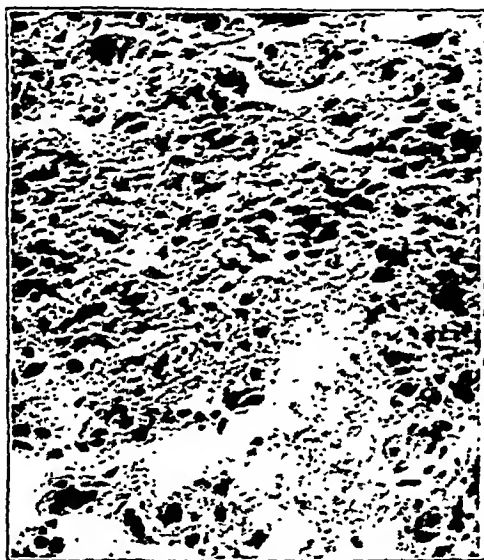


Fig. 12.—Osteofibrosarcoma, grade 3:  $\times 170$ .

on the left, with peripheral neuritis from involvement of the brachial plexus and the cervical sympathetic nerve.

March 16, I explored the tumor through a vertical incision in the left side of the chest wall posteriorly between the scapula and vertebrae. The scapula was not involved, and lateral retraction of it permitted good exposure. There was an extensive infiltrating tumor which seemed to have originated in the first and second ribs, to have extended into the thorax and to have infiltrated the intercostal tissue down the posterior wall of the chest, completely encircling the third and fourth ribs and extending medially into the vertebrae. It was impossible to remove the tumor completely because of its infiltrating character. The accessible portion of the tumor was removed with the third and fourth ribs, and the cavity was packed with gauze. Later, radium was inserted into the pocket when the gauze was removed. Pathologic examination disclosed osteogenic sarcoma, grade 3.

There was moderate shock following the operation, but the patient soon recovered. Radium treatment was given on the fifth day, and the patient

# ANESTHESIA IN EXTRAPLEURAL THORACOPLASTY FOR ADVANCED PULMONARY TUBERCULOSIS

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The surgical treatment of tuberculous patients who no longer respond to a medical or hygienic regimen is beginning to be the accepted procedure in this country, to the great satisfaction of those who have long believed in its efficacy and the possibility of thus bringing help to many patients in an advanced stage of disease.

It is recognized that these patients should not be obliged to travel many hundreds or thousands of miles in order to find specialists who are able to establish the proper indication for operative intervention, and to carry out the required work intelligently and correctly in all its details during and after the operation. It is therefore to be expected that soon every large city in America will have competent medical men who have seen, examined and studied patients of this type from the medical roentgenologic and operative points of view and who have exchanged views and are masters of the required technic. For here the proper regard for details helps in the successful issue of the case in hand; here the harmonious and willing cooperation of internist or phthisicist, of roentgenologist and surgeon will achieve triumphs. Teamwork with the elimination of the personal equation is the watchword; the patient's welfare, the slogan that governs.

That all details in this development will require separate discussion is evident. One of these is the anesthesia. This should be the same as in other parts of the body, local with regional analgesia, general inhalation anesthesia, colonic and a combination of two or more of these.

Always to have the patient's best interest at heart, adapting the method to the patient and not the patient to the method, is a paramount requirement. It does not seem wise to me for the surgeon to say, "In my service all these patients are operated on under general anesthesia," or, "I use only regional and local anesthetics," for he has to deal with such widely differing conditions in these chronic patients that no standardized treatment can do justice to all. One may have a cavity in the upper lobe, the other an additional localized empyema, the third an empyema fistula with involvement of the opposite apex; one may have retained his original morale and undergo the operation with courage and confidence, the other may have lost it completely. For the latter to remain conscious and able to watch the various steps of the operation, although he suffers no physical pain, would mean an addi-

sarcoma. The patient had lost 5 pounds (2.3 Kg.), and appetite and strength had failed markedly during the last two weeks. There was no history of injury, and there had been no respiratory symptoms.

The physical examination was essentially negative except for a large tumor in the posterior part of the chest on the right (scapular region) which pushed the scapula upward and forward. The tumor was hard and slightly tender; it was not attached to the skin except at the site of the recent operative scar over the surface of the tumor. Regional lymph nodes were not involved. The hemoglobin was 72 per cent; the erythrocytes numbered 4,460,000 and the leukocytes 14,700. The results of other laboratory examinations were negative. Roentgen-ray examination of the thorax showed increased density over the fifth, sixth, seventh and eighth ribs and interspaces, with questionable involvement of the lung. The clinical diagnosis was malignant tumor of the right posterior region of the chest wall, probably sarcoma.

December 1, I made a large vertical incision, excising the old scar between the vertebra and the scapula, and obtained good exposure by elevating the scapula. There was a large infiltrating tumor, which involved the posterior third of the fourth, fifth, sixth, seventh and eighth ribs and intervening intercostal tissue from the vertebral attachment laterally. Macroscopically, it appeared to be malignant. The entire mass was removed, including the pleura, and the posterior half of the fourth, fifth, sixth, seventh and eighth ribs. There were areas of infiltration and thinning that indicated apparent involvement of the vertebra, which could not be removed. Radium was inserted in a rubber tube and placed along the vertebra at the time of operation. The pathologic examination showed endothelioma, grade 4. There was little shock following the operation, and there were no postoperative complications. The patient was dismissed from the hospital on the thirteenth day and returned home on the twenty-third day after operation. Relief from pain was only temporary, and about three months after the operation a recurrence involved the spinal cord and caused paralysis of both legs. The tumor recurred in both lungs also, and the patient died five months after the operation.

CASE 5.—A girl, aged 3 years, was admitted, May 7, 1925, because of tumor of the right side of the chest wall. A small tumor just below the right shoulder-blade was first noticed by the parents six weeks before they brought the child to the clinic. It had increased in size rapidly but there was no pain. The child had lost 3 pounds (1.4 Kg.). The tumor had been excised elsewhere ten days before admission, and on pathologic examination it was found to be sarcoma. There were no respiratory symptoms and no history of injury.

The child was well developed but rather poorly nourished; the skin was dry, and there was an appearance of anemia. The hard, firm tumor of the right side of the chest wall in the axillary line was firmly attached to the ribs. The hemoglobin was 40 per cent; the erythrocytes numbered 3,440,000 and leukocytes 8,500, with a normal differential count. The blood Wassermann reaction was negative. The results of other laboratory examinations were negative. Roentgen-ray examination of the thorax showed a circumscribed area with increased density in the lower right lobe and pleuritic thickening at the right base as high as the fourth rib. The clinical diagnosis was malignant tumor of the right side of the bony chest wall, probably sarcoma. Because of recent operation radium was advised, and the patient was asked to return in a month for observation.

The child was brought back for observation, July 8, seven weeks after dismissal. The parents said that her condition had been good for about four

inhalation anesthesia, a straight general anesthesia having been deemed inadvisable in view of the large amount of expectoration present. In a second case, also bronchiectatic, the symptoms of deep collapse set in after operation. Little blood had been lost; only a superficial additional inhalation anesthesia had been employed. The collapse, which did not yield to any kind of subcutaneous or intravenous stimulation, could be attributed only to the method of regional anesthesia.

The Sauerbruch method, which reaches and infiltrates the nerves at the costal angle, appeals more to the surgeon than the Kappis method, and is a simpler procedure. In the hands of Sauerbruch, in whose clinic it originated, and in those of many other surgeons, including myself, it has given satisfactory results, although occasionally the analgesia has been reported to have been incomplete.

It might be a good plan to make it a rule first to anesthetize skin, fascia and muscles and inject each thoracic nerve as it presents itself in the course of the operation at or beyond (medially) the angle of the rib. I believe this procedure has already been accepted as the best and most reliable by many surgeons. The question as to whether the nerves should then best be anesthetized locally with a 0.5 per cent epinephrine hydrochloride-procaine solution injected directly with alcohol, or resected, has not been settled definitely. It seems desirable that different operators should try out these methods in this particular respect and publish the observations made certain a short time after operation, and the after-effects by means of the follow-up system. To know whether the immediate postoperative pains usually observed are reduced or totally absent; to know how long it usually takes for sensation to return after direct alcohol injection, whether the prolonged absence of sensation is in any way annoying to the patient, and similar points is of greatest interest to the prospective operator and will be a valuable guide to him.

#### GENERAL INHALATION ANESTHESIA

I consider it not to the best interest of tuberculous patients to be subjected to a straight ether and oxygen or a gas-oxygen anesthesia, nitrous oxide or ethylene, with a mask placed tightly over the mouth and face. From a prophylactic point of view this method certainly must be inferior to others. Our aim when operating on tuberculous patients should be to hold in check as much as possible aspiration within the lung as well as the discharge of saliva and of mucus in larynx, trachea and bronchial tree; ether inhalation increases the latter. If it is necessary to use straight inhalation, a procedure should be used which permits of holding the mask a distance from the mouth to give the patient a chance to inhale plenty of air. I have reference to the drop method, employing, for instance, a mixture of chloroform, ether and

The physical examination was essentially negative except for a fixed mass, about 5 by 5 cm. in size, which was attached to the anterior axillary line. Results of laboratory examination were negative. Roentgen-ray examination of the thorax shadow just above the diaphragm on the right side, which tumor apparently attached to the ribs and involving the diagnosis was malignant tumor of the right side of the chest wall sarcoma.

February 6, I explored and found the tumor involving the ninth ribs and cartilages. The tumor was radically resected and the wound packed with gauze. Radium was inserted into the wound when the packing was removed forty-eight hours after operation. The pathologic diagnosis was chondrosarcoma. Convalescence was uneventful.

The patient returned for observation and a second course of radium treatment, April 28. There was no evidence of recurrence. He has returned periodically since for investigation and at his last visit, Sept. 10, 1926, he had gained about 5 pounds (2.3 Kg.) and was in good general condition. He was working every day and had had no respiratory symptoms, except slight pain on exertion. There was no evidence of recurrence either by physical or roentgen-ray examination.

CASE 8.—A man, aged 42, was admitted to the Mayo Clinic, Aug. 10, 1925, because of a tumor of the left side of the chest wall. Two months before admission the patient had first noticed a small growth on the anterior wall of the left side of the chest. This had gradually increased in size until at the time of examination it measured approximately 7 by 4 cm. There was no history of pain, injury, loss of weight or respiratory symptoms. Electric treatments had been given; they seemed to increase the size of the growth.

The physical examination was essentially negative except for a firm tumor which was attached to the sternum on the left side of the chest and which involved the second and third ribs. Roentgen-ray examination of the thorax was negative. There was no enlargement of the regional lymph nodes. The clinical diagnosis was malignant tumor of the left side of the chest wall, probably sarcoma.

August 18, I resected the tumor widely. It presented from the second left interspace, close to the sternum, and involved the second and third cartilages, a proximal portion of these ribs and the sternum. The wound was packed with gauze and radium was inserted forty-eight hours after operation. The pathologic examination revealed lymphosarcoma, grade 4.

Convalescence was uneventful, and the patient was dismissed from the hospital on the ninth day and from observation three weeks after operation. In a reply to a questionnaire, sent September 4, he stated that he was enjoying fairly good health but had some pain and dyspnea on exertion. He was able to carry on most of his usual activities. There was no evidence of recurrence.

CASE 9.—A man, aged 45, was admitted to the Mayo Clinic, Oct. 5, 1925, because of a tumor in the left side of the chest. The patient had first noticed a tumor of the left side of the chest below the scapula, six months before presenting himself at the clinic. It had increased in size gradually. There was marked limitation of the motion of the left arm for three months. There had been no pain, loss of weight or respiratory symptoms, and there was no history of injury. Six roentgen-ray treatments had not affected the size of the tumor.



tions for the second stage were made in her room; she thought she was to have an enema, as she had been receiving them frequently. As a deep colonic anesthesia was not desired, less than the usual quantity of ether-oil was given, yet she fell asleep in her bed and did not know she was being transferred to the operating room. A few additional whiffs of anesthetic, administered by an expert, allowed me to carry out the required excision of the upper ribs, including the first. The patient awoke in her room. There was the same perfect primary union of the wound as after the first stage. She was at the hospital five weeks in all. Two months after the second operation, tubercle bacilli could not be found in the sputum on careful search; they had been plentiful when looked for before the surgical work was started. She is now recovering from the unilateral pulmonary tuberculous affection.

Of course the second stage could have been performed under regional and local anesthesia; it could also have been performed under the straight inhalation anesthesia. But that would not have been to the best interest of the patient; it would have meant adapting the patient to the method, instead of the method to the patient.

I am unable to present a series of similar observations, but the experience gathered from one carefully followed case is of value. I have no doubt that a number of members of our association have availed themselves of the advantages offered by colonic anesthesia and its combinations when performing this operation. I feel that a great deal of good can be rendered patients suffering from tuberculous pneumonitis, to whom extrapleural thoracoplasty holds out the only hope of improvement or cure, by carefully selecting the narcotic procedure and remembering colonic anesthesia.

The foregoing holds good, it seems to me, for operations for non-tuberculous lung inflammation, in fact, for thoracic operations in general. Gas positive pressure anesthesia should be added when open pneumothorax is encountered.

#### ABSTRACT OF DISCUSSION

DR. A. L. LOCKWOOD, Toronto: I feel justified in making an effort to defend paravertebral anesthesia. I circularized 200 different men in regard to whether they were doing paravertebral anesthesia by simply catching the nerve at the angle of the rib. I have employed it in 3,000 cases over a period of fourteen years. I have seen only one case in which there was any reaction. In that case I injected in the cervical block. I have stopped doing this. While talking to a group of men present, I injected too much solution. A ptosis in one eye resulted. The woman was not an extremist at all, but she developed partial paralysis of the left arm; this cleared up in ten or twelve days. I have entirely abandoned cervical paravertebral anesthesia, because I do not believe that there is any indication that one can do much with straight local anesthesia from the cervical region down. I have been employing paravertebral anesthesia, in general, as well as thoracic anesthesia, particularly in renal surgery. Probably the greatest bugbear in surgery is the matter of anesthesia. If surgeons can adopt a measure that will take the sting out of anesthesia, they should do it. I agree with Dr. Meyer

after the operation, she again had pain and noticed that the tumor had recurred. The recurring tumor was removed seven months after the first operation and six roentgen-ray treatments were given. The tumor never disappeared entirely after the second operation, and for the month before the patient came to the clinic it had rapidly increased in size. The pain interfered with sleep. She had lost 16 pounds (7.3 Kg.) during the last three years and 8 pounds (3.6 Kg.) in the five months preceding our examination. There were no respiratory symptoms.

Results of physical examination were negative except for evidence of loss of weight and a hard, firm, immovable tumor about 10 by 10 cm., just to the right of the spine on the right side of the lower part of the thorax. There was an old operative scar over half of it. Results of laboratory examinations were practically negative, as were those of roentgen-ray examination of the thorax and of the spine. The clinical diagnosis was malignant tumor of the posterior region of the chest wall on the right, probably sarcoma.

July 8, I removed the eleventh and twelfth ribs on the right posteriorly. A portion of the pleura was removed with the tumor, which extended deep into the lower pleural cavity. The operation was followed by treatment with radium and roentgen ray. The pathologic diagnosis was fibromyxosarcoma.

Convalescence was uneventful, and the patient was dismissed from the hospital, July 26. She returned for a second course of radium and roentgen-ray treatment, September 1. As only three months have elapsed since the operation and the tumor was of the malignant recurrent type, it is too early to draw any conclusions as to the ultimate result.

CASE 12.—A woman, aged 44, was admitted to the clinic, July 27, 1925. Six months before admission she had felt a pain in the anterior portion of the chest on the right and had noticed a lump in the chest wall. The tumor had gradually increased in size, especially during the last few weeks, and there was some pain in the tumor on palpation and some pain in the right arm. Otherwise there had been no pain since the onset. There was no history of injury, no loss of weight and no respiratory symptoms.

The patient's general condition was good. There was an enlargement of the wall of the chest on the right anteriorly, extending from the sternum to the nipple line, and from the second to the fourth rib. The mass appeared to be hard and fixed to the chest wall. The clinical diagnosis was tumor of the wall of the chest on the right, probably sarcoma because of its rapid growth.

At operation, August 4, I found the second and third ribs markedly thinned out anteriorly; a portion of the third rib and cartilage was resected for diagnosis. The pathologic report stated that the rib was markedly thinned in the anteroposterior dimension as though there had been pressure; the maximal thickness was 2 mm., with practically no hove marrow; there was probably an old healed fracture of the third rib.

CASE 13.—A woman, aged 57, was admitted to the Mayo Clinic, June 29, 1925, stating that she had had pneumonia four months before admission and had accidentally noticed a lump in the right breast at that time as the chest was sore. Enlargement of the lump had been noticed about six weeks before admission and continually since then. There was no pain and no history of injury. She had lost 22 pounds (10 Kg.) at the time she had pneumonia, and there had been no gain or loss since then. There was some undue dyspnea on exertion.

Examination disclosed a tumor at the level of the fourth rib, under the lower medial quadrant of the right breast. It was hard and fixed to the chest

# PRELIMINARY ARTIFICIAL PNEUMOTHORAX IN OPERATIONS ON THE OPEN CHEST

WITH CLINICAL OBSERVATIONS ON THE SENSIBILITY AND  
RÉFLEXES OF VARIOUS PARTS OF THE LUNG, AND  
VARIOUS METHODS OF ANESTHESIA \*

LEO ELOESSER, M.D.

SAN FRANCISCO

If the silence of the last ten or fifteen years is an index, it may be assumed that the question of anesthesia in operations on the chest has been solved satisfactorily. This is true for most of the operations surgeons are called on to perform. Procaine hydrochloride, aided occasionally if not regularly by a light nitrous oxide narcosis or a few whiffs of ethyl chloride, gives a satisfactory anesthesia for extrapleural operations—thoracoplasty, avulsion of the phrenic nerve, extrapleural operations on the esophagus and also for more or less extensive thoracotomies when the lung is fixed by a thick and rigid pleura. Local anesthesia with or without nitrous oxide is also satisfactory in that type of operation which we have been led by Evarts Graham to use in suppurative disease of the lung: chronic abscess, chronic suppurative pneumonia and bronchiectasis—a type in which the lung is entered after it has been caused to adhere to the pleura.

Anesthesia for operations that necessitate wide openings into chests containing a mobile lung and mediastinum, however, is still far from satisfactory; and it is toward this kind of attack that surgery of the lung must trend if it is to move with that freedom which open exploration has enabled surgeons to acquire in dealing with the abdominal viscera. Present methods of handling the lung, the intentional provocation of adhesions and obliterative processes, are those which were used in the infancy of abdominal surgery. They are not the ideal to be striven for; they hamper exploration and vision. And while I realize that this cautious and gradual plan of attack has saved many lives and made operations on purulent lungs safer than they were when surgeons were bolder in entering the chest, I feel that the time will come when a better insight into the present difficulties will allow greater freedom, and that the future will lie in open thoracotomies that allow one to feel and see, rather than that in semiclosed operations that confine the maneuvers to small, sealed and unexplorable areas.

The dangers and difficulties of wide thoracotomy lie chiefly in sudden collapse of the lung and in that mysterious phenomenon known for want

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\* From the Division of Surgery, Stanford University School of Medicine.

for the last two years. The pain had been more pronounced during the few weeks before admission to the clinic. There was no loss of weight, no history of injury to the chest wall, and there were no respiratory symptoms.

The results of physical examination were essentially negative except for increased prominence of the fourth rib beneath the right breast. The results of the laboratory examinations were practically negative. Roentgen-ray examination of the thorax was negative. The clinical diagnosis was tumor of the fourth rib on the right, probably benign.

September 22, I explored, and on exposing the fourth rib found marked thickening and bulging of the cartilage. A portion of the cartilage of the fourth rib was removed for diagnosis. The pathologic report was multiple areas of necrosis of cartilage. Convalescence was uneventful.

In reply to a questionnaire, sent Sept. 4, 1926, the patient stated that her general condition was good. She was carrying on her usual activities and had no complaints.

### ABSTRACT OF DISCUSSION

DR. HOWARD LILIENTHAL, New York: I should like to call attention to a point in the after-treatment in cases of this kind and also in the treatment of absolutely inoperable cases, that is, the sarcomas involving the chest wall. I have used the erysipelas and prodigiousus toxins of Coley many times and I have had good success. I think they alone promise an actual cure. Radiation and radium cannot cure. They act locally. A child, aged 2 years, had a sarcoma which involved the mediastinum. It was apparently an inoperable case. The child had been completely paraplegic for several weeks before I saw her, late in the disease. Two ribs had been eroded. I performed a posterior mediastinotomy and removed a specimen about half the size of an egg, which was only a small part of the tumor itself. It proved to be a lymphosarcoma. With no other treatment than Coley's serum, the child was walking in six weeks. She is now over 4 years old. She still has an opacity; evidently some of the tumor is still present in the mediastinum. The ribs have recovered their contour, and the mother refuses to permit further treatment. I think, however, that the child should be treated further. This is only one case, but I have had others. The reason I am mentioning this case is on account of the striking symptom of complete paraplegia. The child was unable to walk and the legs dangled. Now she runs about and seems to be perfectly well. In the cases accompanied by Horner's syndrome, it is rather important in securing the history to get the chronology of the symptom of Horner's syndrome—whether it comes early or late—because it will give one an idea of the place of origin of the tumor. These tumors are likely to spring from the upper thoracic sympathetic ganglions.

DR. WILLY MEYER, New York: Dr. Harrington mentioned metastatic malignant tumors of the chest subsequent to radical excision of the breast for cancer. I have just attended the cancer symposium at Lake Mohonk, and I was impressed when I heard there of a second case—a successful case had been reported by Sauerbruch—in which the total excision of the chest wall was performed by Dr. Semken of New York for a late local recurrence. The patient was still alive two and one-half years after the second operation and remains under observation. Results like these should encourage us to take radical measures in cases of this type.

I should like to mention a case of mine which, after wide resection and microscopic examination, proved to be a metastatic cancer of the chest wall of the hypernephroma type. Several months later the patient developed metastases of the

patient can be allowed sufficient time to accustom himself to the change in his respiratory volume, he will not breathe otherwise when his chest is open than when it is closed. This gradual reduction of the respiratory volume can be accomplished easily by inducing an artificial pneumothorax, in several sittings a week or so before operation. It is astonishing when this has been done to see a patient lie breathing quietly with an opening in the chest wall into which one can easily introduce a fist.

The method has the further advantage of emptying a suppurating lung of secretions, and keeping it empty. When it is used, one no longer sees pus stream in cupfuls from the patient's mouth and nose, as it does when a suppurating lung is suddenly collapsed. The collapsed lung, except for the suppurating area or the bronchiectatic pouches it may contain, is dry and empty.

Preparatory gradual pneumothorax is useful in all free thoracotomies; in tuberculosis it is imperative, for it is extremely harmful suddenly to collapse and distend a tuberculous lung with a positive pressure machine. The method of preparatory pneumothorax seems to have possibilities, perhaps even to open a few new vistas in pulmonary resection for tumors, for inflammatory processes, occasionally even for tuberculosis. Its use is not confined to pulmonary disease; in intrathoracic esophageal tumors it gives an excellent oversight, and it immediately disposes of the powerful suction above the diaphragm which forms the main difficulty in the treatment of diaphragmatic hernia.

Not having Branower's apparatus, and being forced at times to work with anesthetists of varying skill, I have used preparatory pneumothorax only in conjunction with local and rectal anesthesia. If, however, one has an anesthetist whose delicacy is equal to maintaining the balance that Branower calls for, i. e., a pressure that will keep the good lung working and the bad one collapsed, there should be no reason for not combining the method with Branower's inflation anesthesia.

I have used the preliminary pneumothorax and local anesthesia either alone after an injection of morphine and atropine, or in conjunction with rectal anesthesia. For rectal anesthesia, morphine-atropine is given one hour before operation, followed in fifteen minutes by 2 or 3 ounces (59 or 89 cc.) of ether, 2 drachms (7.8 Gm.) of paraldehyde and 2 ounces of olive oil instilled slowly into the rectum. The rectal anesthesia when it works, works well; however, about one patient in three or four is excited instead of being put to sleep by it—an annoying complication, making operation difficult. The patient must not cough or talk; if he makes an expiratory effort against a closed glottis, he will balloon out his collapsed lung. This has happened twice in a series of eleven cases. When it does happen, the incision must be sealed with a wet towel and the patient quieted before operation can proceed.

DR. EDWARD ARCHIBALD, Montreal: I should like to relate briefly a case of my own. A child of 7 years presented a tumor on the right side of the chest. It was difficult by any means at our disposal to determine whether it began in the lung or in the rib. Operation later showed that it had invaded the lung, involving the middle lobe to such an extent that there was little normal tissue left in that lobe. We ultimately came to the conclusion that it had begun in the rib and had extended into the lung as a fibrosarcoma, consisting chiefly of small, round cells. The operation was interesting in the sense that after taking out the section of chest wall surrounding this tumor and entering the pleura, which was adherent, one could lift the middle lobe of the right lung, which formed an integral part of the whole mass, almost completely outside the chest wall. It was a simple procedure to clamp off the healthy lung on either side and cut it away, sew it up, and drop it back. The patient therefore ran a continuous fever, due chiefly to sarcomatosis, and died in the course of three months, with metastasis through the body, particularly in the scalp.

In another cases of fibromyxosarcoma of the chest six operations were performed. Finally, the patient went to Liverpool to consult Blair Belle and receive the lead treatment. He was able to take only four injections, as they caused severe cramps, both in the abdomen and in the legs; they did not benefit him. Recently he returned to this country with a recurrence of his fibromyxosarcoma and suggestive signs in the lung, although that could not be definitely determined by the roentgen ray. I mention the lead treatment because this was a case in which it might have accomplished good, as the tumor was malignant only locally while under observation for more than a year, yet lead accomplished nothing.

DR. J. J. SINGER, St. Louis: I want to make this suggestion in the differentiation between a tumor of the chest wall and a tumor of the thorax: By the introduction of a diagnostic pneumothorax one can easily push the lung away and tell where it is, assuming, of course, that there are no direct adhesions between the lung and the tumor of the chest wall.

of the severed pulmonary veins, and the cough forces a great volume of air or infectious material into them under great pressure. Besides these immediately fatal sequels, the paroxysms of coughing aspirate and insufflate gangrenous material from one part of the lung to another and cause new areas of gangrene; a fatal pneumonia has followed injection of surgical solution of chlorinated soda (Dakin's solution) into an unsuspected bronchial fistula, the solution having been coughed violently into unaffected parts of the lung.

It has been noted curiously that the seat of this cough reflex seems to lie in the ciliated bronchial epithelium. The bronchial mucosa is extremely sensitive when it has been recently exposed; after a time the lung contracts and the open bronchi correspondingly widen, giving the exposed lung the appearance of a reticulated bladder (or as Sauerbruch terms it, a gridiron lung); the epithelium of the exposed bronchi and lung changes from ciliate to squamous. After this change the epithelium seems to lose its cough reflex; it may be touched with cotton or swabbed with various irritating solutions without causing a paroxysm. Neither does the reflex lie in the lung itself; irritating the raw section of the lung has no effect, provided care is taken to avoid open bronchial lumina. Further proof that the reflex is entirely one of the surface and of the mucosa itself lies in the fact that instillation of cocaine abolishes it.

We are indebted to Sargent and Forestier for this useful help to anesthesia. They anesthetize the bronchi with cocaine before injecting iodized oil. As the cough reflex is abolished by this method, it was a natural step to use it in operations in which open bronchi were to be encountered. If an open bronchial fistula exists, from 1 to 2 cc. of 4 per cent cocaine solution with 5 drops of epinephrine hydrochloride is instilled into it with an eye dropper or a syringe. The patient promptly reacts with a cough, sprays the cocaine about through his bronchial tree, coughs some of it out and then coughs no more. If the bronchi are not open, a hypodermic needle is introduced into the trachea between two of its rings, and 1 or 2 cc. of 4 per cent cocaine-epinephrine hydrochloride solution is injected into it. Procaine hydrochloride would probably be safe; I have not tried it.<sup>1</sup> One must be sure that the needle is in the trachea; the plunger should always be pulled back and air drawn from the tracheal lumen before cocaine is injected. The bronchial mucosa reacts almost immediately; the cocaine itself causes a cough, but a minute or two later the mucosa is insensitive and excites no further paroxysm when it is handled.

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1. But I shall. Two recent respiratory disturbances after cocaine were alarming enough to dissuade me from the use of this drug if procaine can be used in its stead.

tional psychic ordeal, which should be avoided if possible. The mental make-up of the patient should receive special consideration, particularly when it appears advisable to operate in stages.

The gist of these reflections is the necessity for the operator to master the various procedures that make the surgical work painless and, as far as possible, safe.

#### LOCAL AND REGIONAL ANESTHESIA

Today there can be no question that from the standpoint of safety local and regional anesthesia in the chest, as well as elsewhere, occupies first place. It is evident that if in the presence of a chronic lung suppuration, for instance, the patient retains the ability to sense irritation and the ability to expectorate, he is better off than without these powers. Yet individual characteristics may present a clear contraindication to the method stated and force operators to employ the next best procedure, and trust that it may prove equally beneficial.

For the operation of extrapleural thoracoplasty a variety of well worked out methods are at the surgeon's command. He will naturally select the one that in his opinion involves the least amount of risk for the patient, and train his staff in this method. If he does not wish to prepare the patient himself, he can turn this part of the work over to the anesthetist before he starts the superficial as well as the deep surgical work required during the operation; every anesthetist should be master of a reliable, harmless technic. Or, the surgeon himself can proceed with the primary analgesic work in the soft parts and then, under the guidance of his eyes, expose and inject into or around the individual intercostal nerves as they present themselves as near the spine as possible.

For a complete primary preparation the so-called Kappis and Schumacher methods are at our disposal. I myself used the Kappis paravertebral method exclusively in my earlier operations for multiple rib resection in bronchiectatic and tuberculous patients. But in view of a few experiences several years ago and the additional warnings found in the literature,<sup>1</sup> I was induced to give up the procedure in spite of its advantage in permitting one to reach the thoracic nerves near their origin and their communication with the ganglions of the sympathetic system. In one of my cases, a bronchiectatic, profound collapse occurred on the table before the operation was commenced. I had no doubt that the point of the needle had entered the subdural space here or there. The operation had to be postponed for several days and then carried out with a combination of local, regional and superficial

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1. Friedrich, H.: *Centralbl. f. Chir.* 53:1441 (June 5) 1926.



The visceral pleura and the surface of the lung are quite insensible; neither is the normal parietal pleura extremely sensitive. Patients have not complained of pain when retractors have been introduced into the chest or when the parietal pleura has been touched, so that extensive subpleural infiltration with procaine or extensive blocking of the intercostal nerves has not seemed necessary. Pleuritic adhesions, however, are extremely sensitive; the inflamed pleura probably reacts more keenly to stimuli than the normal one. Patients complain bitterly when adhesions are touched or pulled on; even large subpleural injections of procaine hydrochloride have not sufficed to make their division painless.

#### PROCEDURE IN OPEN THORACOTOMY

A week or ten days before operation artificial pneumothorax is induced; 750 cc. of air is usually given at the first sitting, two or three days later 1,000 cc., and again after two or three days another 1,000 cc. The amounts and intervals vary; the object is to produce a complete collapse of the affected side without compressing it strongly enough to push the mediastinum toward the sound side. Insufflation of air will therefore stop when the manometer reads zero. Bronchiectatic lobes collapse incompletely; after pneumothorax the sound lobes are completely collapsed; the bronchiectatic one projects into the pneumothorax, being kept distended by its fibrosis and rigidity. An hour before operation one-fourth grain of morphine and  $\frac{1}{150}$  grain of atropine are given. This is sometimes followed in fifteen minutes by a mixture of 2 or 3 ounces (59 or 89 cc.) of ether, 2 drachms of paraldehyde and 2 ounces of olive oil instilled slowly into the rectum through a fine catheter. Rectal ether seems to work best in placid, phlegmatic patients; it seems to excite excitable ones; weak or frail ones seem to stand it badly or are slow to recover from its effects. An additional one-sixth grain (0.01 Gm.) of morphine may be given just before operation. It is not necessary to have the patient empty his lung by coughing; the preliminary pneumothorax has emptied it for him.

A 0.75 per cent solution of procaine hydrochloride containing 2 drops of 1:1,000 epinephrine hydrochloride to the ounce is injected subcutaneously along the line of incision in order to save waiting twenty minutes for a nerve block to take effect, but the intercostal nerves innervating the same line are injected with the same solution. If the lung is to be severed, 1 or 2 cc. of 4 per cent cocaine or procaine hydrochloride solution with 5 drops of epinephrine hydrochloride is injected into the trachea with the patient upright or semierect. Much of this cocaine is expelled by coughing. In extrapulmonary operations the air passages are not anesthetized by cocaine. The chest is now opened and operation proceeds.

I do not know whether to recommend subpleural injection of procaine hydrochloride at the hilum. It was effective in a recent operation for esophageal carcinoma; in a recent lobectomy it was not, but here the patient was excited and talkative after rectal anesthesia.

I should like to make it clear that I am not warmly advocating local anesthesia in thoracotomy. I am not sure of its advantages; indeed, I am sure that a general narcosis, if it can be safely carried out, is much to be preferred, and is easier and less shocking to the patient than

ethyl chloride. This is a narcotic the boiling point of which is adapted to the temperature of the body; for this reason it is safer than pure chloroform and safer also than the old Billroth mixture.

#### COLONIC ANESTHESIA

Colonic anesthesia is best combined with inhalation anesthesia, according to the indications. The great advantages of this method of inducing analgesia are principally due to Gwathmey's happy conception of mixing the ether with olive oil. When so prepared, the anesthetic is gradually and slowly given off; it is absorbed into the blood that circulates in the intestinal mucosa, passes with the blood through the liver and right side of the heart and is then continually given off to the outflowing respiratory volume of air in the alveoli of the lungs and in the bronchial mucosa. The patients are semiconscious and able to expectorate without experiencing pain.

Experiments on animals have shown that the effect produced by a slow and steady discharge of ether within the respiratory system is equal to an artificial hyperemia which, according to Bier's method of hyperemia, has a good, not a destructive or dangerous, effect on the patient's lung. This at least has been observed in cases of acute bronchitis and threatened pneumonia subsequent to ether inhalation anesthesia, also in patients suffering from chronic bronchitis due to alcohol or tobacco.<sup>2</sup> Here the ether was administered by intramuscular injection into the gluteal region, 8 minims (0.5 cc.) of ether mixed with an equal amount of sterile olive oil. By proceeding in this way the whole volume of ether also does not enter the blood at once as in the ordinary hypodermic application, but it is given off, step by step, from the artificially made deposit within the muscular substance.

There is to my mind no reason to expect harm from the use of this method in the specific types of chronic pulmonary inflammation, such as tuberculous and syphilitic, or in nonspecific suppuration of the lung. Clinical observation will soon decide this point.

In a recent case of mine this form of inducing sleep and analgesia proved to be of invaluable merit:

A much reduced, highly nervous tuberculous patient of Italian extraction needed extrapleural thoracoplasty. The right side alone was involved; pleural adhesions prevented the continuance of artificial collapse of the lung, which had been tried for some time. A two-stage operation appeared advisable, the first stage (lower ribs) to be performed under procaine, regionally and locally applied. The patient herself was unaware of the necessity of a second operation. Her psychic state forbade my telling her; the relatives, of course, knew. The prepara-

2. Riess: *München. med. Wchnschr.* 72:758 (May) 1925. Seidl: *ibid.* 73:95 (Jan.) 1926.

had never heard of anybody repeating it. I still believe there is a place for this method of producing pneumothorax in cases in which the presence of adhesions makes an ordinary injection of air into the chest cavity impossible.

DR. HOWARD LILIENTHAL, New York: I was interested to hear of the application of the pneumothorax method, which I had known of before and read of in the literature. It has been recommended, in the discussion of operations on lung tumors, as a preliminary step.

I must take issue with Dr. Eloesser on the question of pleural or pulmonary reflex. His patient had been operated on; there was induration, bleeding and an open bronchus. That induces cerebral air embolism. This accident will be seen only in cases in which there has been previous operation or previous disease leading to infiltration of the parts, so that the branches of the pulmonary vein are held open. It takes surprisingly little air to get into one of these open veins and go directly to the brain, producing a series of convulsions and death. I think if Dr. Eloesser will read Schlaepfer's article on this subject, he will be convinced that pleural shock does not exist as such. People have tried to produce pleural shock by painting the pleura of animals with iodine. I do not think they have succeeded. I do know I have painted the pleura of half the chest with iodine in order to make adhesions, and I have done it three or four times without a sign of shock. In three days the iodine will make adhesions. This is done as a preliminary to lobectomy. I think it is important that this society should not tacitly give its consent to the idea that there is such a thing per se as pleural or pulmonary shock.

DR. CARL HEDBLUM, Chicago: I should like to discuss some phases of the general problem of pneumothorax, but this is not the time to introduce that subject. I do want to say that I believe there is something that is not as yet understood concerning so-called pleural or pulmonary reflex or pleural eclampsia, or whatever it may be called. I believe that there are different types and that there are different causes for the same clinical manifestations, more or less. For instance, within the last month I had a patient on whom I was going to perform a second stage extrapleural thoracoplasty for bronchiectasis. I had just opened the incision that I had made at the first operation when the patient went into convulsions. The pupils dilated; she became intensely cyanosed, and apparently reached the last stage of dissolution, then gradually revived. I cannot see how these symptoms could possibly have been due to air embolism. The pleura was not touched. Possibly the nitrous oxide anesthesia was the etiologic factor. I have had other cases which in my opinion cannot be explained as due to air embolism. There is more to the problem of so-called pleural reflex, I believe, than air embolism. I was very much interested in Dr. Eloesser's presentation of the matter of pneumothorax preliminary to thoracoplasty. As Dr. Lilienthal has just said, the method was described years ago. Under certain conditions it seems worth further trial, but I would want to be conservative in the matter of thoracotomy for pneumolysis in pulmonary tuberculosis. I have had patients who have developed tuberculous empyema with complete collapse of the lung following such operations performed elsewhere, and some of those have been among the most difficult I have had to treat.

DR. WILLY MEYER, New York: The paper of Dr. Eloesser is interesting, even if he has not been the first to do what he did. It shows how a surgeon can sometimes help himself under difficult conditions. I should like to mention the original statement of Sauerbruch, that it would be wrong for the surgeon to

that only 1 per cent of procaine should be used as an anesthetic, and after treatment 5 per cent.

DR. WILLY MEYER, New York: After having thought of my personal experience and studied the literature, and seen an unfortunate older patient this summer, I am through with the paravertebral method of anesthesia. This patient had had a persistent intercostal neuritis subsequent to a herpes zoster. She was admitted to a hospital and placed in the care of an expert in paravertebral anesthesia for angina pectoris. She walked to the operating table. The specialist made the injection with alcohol. The woman was asked to get up. She could not. She had to be lifted onto a stretcher and brought to her bed because of a total paralysis of the lower portion of the body, bladder and rectum, which continued and soon took her life. One such case is enough for me.

## PROCEEDINGS

WEDNESDAY, SEPTEMBER 29—EVENING

The council met at the Mount Royal Club at 9:30 p. m.

THURSDAY, SEPTEMBER 30—MORNING

The meeting was called to order at 9 a. m. by the president, Dr. Edward W. Archibald, at the Ritz Carlton Hotel.

Dr. Stuart W. Harrington, Rochester, Minn., read a paper on "The Surgical Treatment of Intrathoracic Tumors and Tumors of the Wall of the Chest." Discussion was opened by Dr. Howard Lilienthal, New York, who was followed by Drs. Willy Meyer, New York; Leon T. LeWald, New York; Carl A. Hedblom, Chicago; Jacob J. Singer, St. Louis; Edward W. Archibald, Montreal, and Stuart W. Harrington, Rochester, Minn.

Drs. Adrian V. S. Lambert, New York, and Frank B. Berry, New York, by invitation, presented a paper on "The Mediastinum: Anatomic and Clinical Study." Discussion was opened by Dr. Hugh Auchincloss, New York, who was followed by Drs. Howard Lilienthal, New York; Nathan W. Green, New York; William Lerche, St. Paul, and Adrian V. S. Lambert, New York.

Dr. David T. Smith, Ray Brook, N. Y., by invitation, read a paper on "Experimental Aspiratory Abscess." Discussion was opened by Dr. Willy Meyer, New York, who was followed by Drs. Adrian V. S. Lambert, New York; Howard Lilienthal, New York; Nathan W. Green, New York; Frederick T. Lord, Boston; Leo Eloesser, San Francisco, and David T. Smith, Ray Brook, N. Y.

Dr. Frederick T. Lord, Boston, read a paper on "The Diagnosis and Treatment of Eventration of the Diaphragm, with a Report of Four Cases."

Dr. Edward N. Packard, Saranac Lake, N. Y., by invitation, read a paper on "Hernias of the Mediastinum During the Course of Artificial Pneumothorax."

These two papers were discussed by Drs. Jacob J. Singer, St. Louis; Carl A. Hedblom, Chicago; John L. Yates, Milwaukee; William Lerche, St. Paul; Leo Eloesser, San Francisco; Willy Meyer, New York; Howard Lilienthal, New York; Leon T. LeWald, New York; Edward S. Welles, Saranac Lake, N. Y., and Frederick T. Lord, Boston.

THURSDAY, SEPTEMBER 30—AFTERNOON

The meeting was continued at the Ritz Carlton Hotel.

The following papers were read as a symposium on "Lung Mapping by Insufflation and Bronchoscopic Injection Methods, and the Roentgen-Ray Interpretation thereof."

Dr. Jacob J. Singer, St. Louis: "Bronchography (Injection of Iodized Oil, 40 per cent)."

Dr. Gabriel Tucker, Philadelphia: "The Technic of Bronchoscopic Introduction of Bismuth Subcarbonate and Iodized Oil, 40 per cent, for Pneumonography."

Dr. David H. Ballon, Montreal, by invitation: "Pneumonography with Iodized Oil, 40 per cent, by the Bronchoscopic Method."

Dr. David A. Stewart, Ninette, Manitoba: "Etiology and Differential Diagnosis in Septic Conditions of the Chest."

of a better term as a "pleural reflex." To these there is added, whenever the larger bronchi are approached, a cough reflex. If operators can learn to cope with these three factors, the sudden collapse, the pleural (I think rather, pulmonary) reflex and the cough, it will be possible to work with freedom in the open chest.

Sudden collapse is not the correct term for the chief difficulty. All sudden variations in lung volume, both sudden collapse and sudden inflation, are equally objectionable. Both make a sudden variation in the volume of blood that is thrown into and sucked out of the heart. Both are equally terrifying in their effects on the circulation.

Positive and the older negative pressure methods partly avoid a sudden collapse, of course—partly but not entirely, for the lung is purposely inflated and allowed to collapse during all the pressure methods of anesthesia. Nearest perfect is Branower's method, which so cleverly balances the pressure that the lung in the unopened side of the chest is kept working and the mediastinum kept in place while the lung in the open side of the chest is allowed to collapse. Even here it seems necessary occasionally to inflate the lung. Branower says, "The anesthetist should carefully observe the condition of the operative lung from time to time, and should frequently request the surgeon for an opportunity to inflate it. This has a wonderfully stimulating effect upon the patient." Even this delicate method seems to tax the powers of a patient severely. Branower states that "an operation of more than forty to forty-five minutes' duration is not likely to be followed by recovery."

The pressure method, therefore, has its inherent disadvantages. It is interesting to see how quickly it tires a normal person to breathe against a pressure mask, although this effort is only a small part of the strain of a pressure anesthesia. Even were it possible to keep the lung evenly distended, the surgeon would have no room to work. He needs a certain amount of collapse. If the lung is kept distended, the patient does not get rid of his tidal air: on the other hand, he cannot stand its being kept collapsed. The necessary alternative is an occasional variation from collapse to distention. This shift is a strain on the surgeon, for each time it occurs his field shifts many inches, and he is forced again and again to readjust his manipulations. Much more is it a strain on the patient's heart, so terrifying a one that I thank God every time I am able safely to complete an operation when I have entered the chest under positive pressure. It is impossible to work with equanimity under these distressing difficulties.

Is it possible, then, to avoid the respiratory and circulatory disturbances that accompany these sudden changes in the volume of the lung? It is. The disturbing element in the changes is their suddenness. If they can be made gradual, if the lung can be collapsed, and before the chest is opened the negative pressure abolished in it, if the

Dr. John L. Yates, Milwaukee, read a paper on "Rationale of Operations Helpful in Promoting Recoveries from Pulmonary Tuberculosis." Discussion was opened by Dr. Edward W. Archibald, Montreal, who was followed by Drs. Adrian V. S. Lambert, New York; Howard Lilienthal, New York, and A. T. Lockwood, Toronto.

Dr. Edward S. Welles, Saranac Lake, N. Y., read a paper on "An Accessory Thoracoplastic Operation to Aid in the Collapse of Large Tuberculous Cavities."

Dr. Willy Meyer, New York, read a paper on "Anesthesia in Tuberculous Patients Requiring Extrapleural Thoracoplasty." Discussion was opened by Dr. A. T. Lockwood, Toronto, who was followed by Dr. Willy Meyer, New York.

Dr. William Lerche, St. Paul, read a paper on "Infected Mediastinal Lymph Nodes as a Source of Mediastinitis." Discussion was opened by Dr. Edward W. Archibald, Montreal, who was followed by Dr. William Lerche, St. Paul.

Dr. Leon T. LeWald, New York, read a paper on "Congenital Absence of the Left Half of the Diaphragm."

#### SATURDAY, OCTOBER 2—MORNING

The meeting was continued at the Royal Victoria Hospital.

Operative clinics and dry clinics were held by Dr. Edward W. Archibald and other Montreal members of the association.

Finally, the mild inflammatory thickening that results from the presence of air in the pleura is not the least of the advantages of preliminary pneumothorax. The stability of adhesions, once they form in an artificial pneumothorax, is notorious. Adhesions form quickly and firmly after operation, i. e., at a time when they are desirable. Absorption from the thickened pleura seems to be less sudden and less dangerous than from a normal one, so that the mild pleurisy is a protection in lobectomies and other operations in which the pleura is likely to be contaminated with pus.

I shall not reopen the question of open lobectomy versus the cautery operation here. I am ashamed of the mortality after my lobectomies. However, the preliminary pneumothorax seems to give hope for lobectomy in bronchiectasis, an operation which (if it could be carried through with equal safety) would be preferable both in quickness and completeness of recovery to repeated cauterization.

Pleuritic adhesions may make it impossible to induce an artificial pneumothorax. When pleurisy occurs it usually accompanies suppurative affections of the lung, which call for drainage and not for extensive resections of a part or all of a lobe: in this type of operation free thoracotomy is uncalled for; pleurisy is welcome and necessary before the chest is entered.

In bronchiectasis, in tumors and in diseases of the esophagus and mediastinum that call for a wide open thoracotomy, adhesions rarely interfere with induction of a pneumothorax.

Preparatory pneumothorax has been used in eleven cases: five intrapleural pneumolyses for pulmonary tuberculosis, with adhesions preventing complete collapse, two bronchiectases, three esophageal carcinomas and one exploratory thoracotomy for bronchial stenosis.

A further adjunct to anesthesia in which bronchial lumina are exposed or are to be exposed is abolition of the futile and dangerous paroxysm of coughing that occurs whenever the bronchial epithelium is touched. Patients with wide open bronchial fistulas have served as interesting subjects in the study of this reflex. For days after the bronchi are opened, even the gentlest touch of their epithelium with cotton will send the patients into a violent and entirely uncontrollable spasm of coughing. The cough alternates between several violent true coughs (forcible expulsion of air against the closed glottis) and a deep whoop or gasp as an interlude. The paroxysmal cough is annoying, and makes operation impossible while it continues; it is futile, and occurs not as a purposeful reflex because the patient has something to cough out, but because the bronchial mucosa is touched, and whether he has something to cough out or not. If the cough is annoying and futile, the sequence of cough and whoop is much more: it is dangerous. It is the cause of some of the fatal accidents that beset operation on the lung and against which the surgeon is powerless. The whoop probably opens the mouths



office and neither may be reelected to succeed himself in the same office. The Secretary and the Treasurer shall be elected for a one year term of office and either or both may be reelected indefinitely. The outgoing president shall automatically become a councilor for a one year term of office. The other four councilors shall be elected, one each year, for a four year term of office, but no councilor may be reelected to succeed himself.

SEC. 3.—Vacancies occurring among the officers and councilors during the year shall be temporarily filled by action of the Council, subject to approval of the Association at the next regularly convened meeting.

#### ARTICLE VI.—COMMITTEES

SEC. 1.—At the opening session of the annual meeting there shall be elected after nomination from the floor of the Association a Nominating Committee of three. This Committee shall prepare a slate of nominees for officers and councilors and shall present their report at the executive session of the Association.

SEC. 2.—The Council is empowered to appoint a Membership Committee, an Auditing Committee, a Committee on Program and Transactions, a Necrology Committee and such other committees as may in its opinion be necessary. All such committees shall render their report at the executive session of the Association.

#### ARTICLE VII.—FINANCES

SEC. 1.—The fiscal year of the Association shall coincide with the calendar year. The books of the Association shall be kept and audited on this basis.

SEC. II.—Members shall contribute to the financial maintenance of the Association through the medium of initiation fees, annual dues and special assessments. The amount of the annual dues and the initiation fees shall be determined by the By-Laws.

Special assessments may be charged against individual members, as determined by the By-Laws, when material submitted for publication in the annual transactions of the Association exceeds such limits as may be set in the By-Laws. If, at the end of any fiscal year there be a deficit in the current funds of the Association, the Council may send out notices to that effect and invite Active Members to contribute the necessary amount so that no deficit be carried over from one fiscal year to another. The Association may, in any regularly convened meeting, vote a special assessment for any purpose whatever, and such special assessment shall become an obligatory charge against the classes of members affected thereby.

SEC. III.—To meet the current expenses of the Association, there shall be available all revenue derived from annual dues, special assessments, and income from Endowment Fund, subject to the provisions of Section IV following. Funds derived from the payment of initiation fees shall not be available for current expenses.

SEC. IV.—All funds derived from the payment of initiation fees shall be placed in a special fund, to be invested and reinvested in legal securities, and to be held intact as an Endowment Fund. The Council is responsible for the proper management of the Endowment Fund. The income from this fund may be utilized for such purposes as may be determined in the By-Laws. If at the end of any fiscal year there be a surplus in the current funds of the Association, the Council may divert such surplus into the Endowment Fund, but in no case may the

The persistent paroxysmal cough of mediastinal pleurisy and conditions at the root of the lung might cause suspicion that the cough reflex may originate elsewhere than in the bronchial mucosa. This is true; manipulation of certain places at the hilum or in the mediastinum will cause paroxysms even after the bronchial mucosa is anesthetized.

H. J. had an exploratory thoracotomy done under local anesthesia and preliminary pneumothorax for an intermittent bronchial stenosis of unknown, probably extrabronchial, origin. At operation many dense adhesions were discovered between the medial surface of the left upper lobe and the mediastinum. Severing or making traction on these caused a cough so violent that it was almost impossible to hold the distended lung aside, neither anesthetizing the bronchus with cocaine nor a light chloroform inhalation anesthesia sufficed to stop the cough.

The so-called pleural reflex remains for comment. This had better be called the pulmonary reflex. In none of the deaths reported after pleural puncture can one be sure that the lung was not entered. The greater vessels of the lung are extremely sensitive; clamping them or transfixing them with a ligature not infrequently causes profound shock. This has been noted in cases in which air embolism and other causes of sudden death can be excluded.

Mrs. F., aged 42, was operated on with a galvanocautery for bronchiectasis. The pleura had been caused to adhere. Two weeks later, the wound was opened under gas and local anesthesia. The packing was removed. The lung was adherent to the pleura. An attempt was made to find a bronchus with a needle in order to inject cocaine; however, as no air appeared in the syringe, cocaine was not injected. Then with a cautery a pyramidal piece of lung was excised which included a section of bronchus about the caliber of a slate pencil and 1.5 cm. long. Cocaine was injected into this bronchus centrally; a grooved director was inserted into it distally, and the distal tract slit with a galvanocautery, opening a bottle-shaped bronchiectasis half the size of a walnut. The central end was followed to within 1.5 to 2 cm. of the hilum. A spurting branch of the pulmonary artery was grasped with a Kocher hemostat. At this juncture the patient, who had hitherto breathed and had given the anesthetist no anxiety, suddenly stopped breathing. She was turned around. She was pale, and no heart sounds were to be heard. It was apparent that death was due to heart failure and not to failure of respiration. One cubic centimeter of pituitary extract was injected into the chamber of the heart, but the pulse never again appeared.

At necropsy the right side of the heart was found dilated to two or three times the size of the left.

Whether injection of procaine hydrochloride under the pleura of the hilum of the lung can diminish the intensity of this reflex or abolish it remains to be seen. For the present, I think it safer to anesthetize the patient with nitrous oxide before clamping or tying the vessels at the root of the lung. The anesthetic, it is true, will distend the collapsed lung; however, after the root of the lung has been secured by clamps or ties and the operation is almost ended, distention of the lung is no longer objectionable.

# LIST OF MEMBERS OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

## Honorary Members

Dr. Edward R. Baldwin.....	6 Church St., Saranac Lake, N. Y.
Dr. Alexis Carrel.....	Rockefeller Institute, New York.
Dr. Norman B. Carson, c/o Mrs. Newton B. Wilson,	4 Brentmoor Park, St. Louis.
Dr. Georges Dehelly.....	25 Rue Henry Genestal, Le Havre, France.
Dr. Alfred Meyer.....	Apt. 16 E., 1225 Park Ave., New York.
Dr. S. Adolphus Knopf.....	16 West Ninety-Fifth St., New York

## Active Members

Dr. John Alexander.....	The Corey Hill Hospital, Brookline, Mass.
Dr. Carroll W. Allen.....	509 Macheca Building, New Orleans.
Dr. Duff S. Allen.....	Washington University Medical School, St. Louis
Dr. William DeWitt Andrus.....	Cincinnati General Hospital, Cincinnati.
Dr. Edward W. Archibald.....	52 Westmount Boulevard, Montreal.
Dr. Hugh Auchincloss.....	Presbyterian Hospital, New York.
Dr. A. T. Bazin.....	Montreal General Hospital, Montreal.
Dr. Emil G. Beck.....	2551 North Clark Street, Chicago.
Dr. Ralph B. Bettman.....	104 South Michigan Avenue, Chicago.
Dr. Frank K. Boland.....	436 Peachtree Street, Atlanta, Ga.
Dr. William Branower .....	1815 Seventh Avenue, New York.
Dr. Lawrason Brown.....	104 Main Street, Saranac Lake, N. Y.
Dr. Harold Brunn.....	350 Post Street, San Francisco.
Dr. Ethan F. Butler.....	Robert Packer Hospital, Sayre, Pa.
Dr. J. Roddick Byers.....	74 Westmount Boulevard, Montreal
Dr. A. H. W. Caulfield.....	13 Spadina Road, Toronto
Dr. Rufus Cole.....	960 Park Avenue, New York.
Dr. Samuel J. Crowe.....	Johns Hopkins Hospital, Baltimore.
Dr. Armistead Crump.....	20 West Fiftieth Street, New York.
Dr. Elliott Carr Cutler.....	Lakeside Hospital, Cleveland.
Dr. T. C. Davison.....	Suite 35, Doctors' Building, Atlanta, Ga.
Dr. Victor P. Diederich.....	Hot Springs, Ark.
Captain Chauncey E. Dovell, M.C., U. S. Army.....	Fort Monroe, Va.
Dr. Kennon Dunham.....	1020 Union Central Building, Cincinnati.
Dr. Edmond M. Eberts.....	219 Peel Street, Montreal.
Dr. Carl Eggers.....	850 Park Avenue, New York.
Dr. Max Einhorn.....	20 East Sixty-Third Street, New York.
Dr. Leo Eloesser.....	738 Butler Building, San Francisco.
Dr. Charles A. Elsberg.....	64 East Fifty-Eighth Street, New York.
Dr. R. G. Ferguson.....	Saskatchewan Sanatorium, Fort Qu'Appelle, Saskatchewan.
Dr. Hermann Fischer.....	73 East Eightieth Street, New York.
Dr. Sparrell S. Gale.....	Lewis-Gale Hospital, Roanoke, Va.
Dr. Conrad Georg, Jr.....	117 E. Liberty St., Ann Arbor, Mich.
Dr. Evarts A. Graham.....	Washington University Medical School, St. Louis.
Dr. Nathan W. Green.....	152 West Fifty-Seventh Street, New York.
Dr. Fraser B. Gurd.....	115 Stanley Street, Montreal

these tours de force with local anesthetics. I am, however, equally sure that preliminary artificial pneumothorax with collapse of the affected lung is of great value, and that pressure anesthesia with its unavoidably sudden and violent inflation and collapse of the lung is harmful. So rather than dispense with the ease and accuracy and ability to see that go with operation on a patient who is breathing quietly and without strain, with a lung that lies collapsed and out of the way at the bottom of the chest, I have resorted to the methods of overcoming pain without disturbing the respiratory equilibrium of the open pneumothorax that I had at my disposal, namely, local anesthesia and rectal ether anesthesia. If, however, Branower's machine will let the collapsed lung stay collapsed and keep the unaffected one breathing quietly while the patient is under general anesthesia, then this method in combination with preliminary pneumothorax and blocking of certain of the intercostal nerves should be ideal.

Quiet respiration is a *sine qua non* for the maintenance of collapse, so that combination with any of the ordinary inhalation methods of anesthesia is not feasible.

#### SUMMARY

Preliminary artificial pneumothorax is a valuable aid in open thoracotomy for operations on the thoracic viscera.

It causes less shock and less circulatory disturbance than any of the pressure methods of anesthesia.

It may be used in conjunction with local anesthesia, and aided further by rectal ether anesthesia; possibly, by certain forms of inhalation anesthesia.

Irritation of the bronchial mucosa causes a paroxysmal cough reflex.

This reflex disappears after the open bronchial mucosa changes from ciliary to squamous epithelium.

Abolition of the paroxysmal cough reflex by anesthetizing the bronchial tree with cocaine is valuable in opening into the bronchial lumen.

490 Port Street.

#### ABSTRACT OF DISCUSSION

DR. FRANZ TOREK, New York: I was interested in hearing that Dr. Eloesser has used the intrapleural pneumolyses in five cases. I wrote an article on this topic about twelve or thirteen years ago. That was previous to the time that thoracoplasty had reached its present perfection of technic. I have never had occasion to repeat the operation, because tuberculous patients are not admitted to the hospital with which I am connected. This particular patient was there by accident; she was so sick she could not be sent away. But I would have repeated the method. I am glad to hear that somebody else has done it and has persisted in doing it; Dr. Eloesser repeated it five times. I had believed that the consensus of opinion was that my operation was worthless, because I

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use local anesthesia within the healthy pleura. He made his statement after he had performed a great many operations. He says that it is absolutely necessary to use general anesthesia. It is known that the nerves play an important rôle in thoracic operations in which the pleura is wide open. With so many thoracic operations being performed at the present time, it will be of interest to follow this question further as to the use of regional and local anesthesia.

DR. LEO ELOESSER, San Francisco: Dr. Torek has driven me into a corner. I hesitated to bring my misdemeanors before this august assemblage. I approached the intrapleural pneumolyses with anxiety; I performed four in 1922, then stopped until this year, when I performed one. But God was good to me. Three of the patients are cured and one much improved. Of course it is too early to report on the operation performed this year. I am sorry not to have been more explicit in my designation of the pulmonary reflex. It is not a pleural reflex; it is a pulmonary reflex. I am grateful to Dr. Lilienthal for calling my attention to deficiencies in reading; I looked about for descriptions of pneumothorax as a method preparatory to anesthesia but was unable to find any. I shall look up Ballinger's method. I have not seen it used at any of the clinics I have visited. Of course, I do know Schlaepfer's work and was extremely interested in it. In fact, I had an ophthalmologist, Dr. Barkan, look at the eyegrounds of various rabbits on which these procedures were attempted. He could see bubbles of air in the retinal vessels, just as Becker and Stargardt did, when there was a pulmonary air embolism. However, the patient I spoke of did not die of air embolism. She died after clamping a pulmonary artery. I was particular to make as careful a necropsy as I could. There was no air embolism, but the right side of the heart was much dilated. Dr. Meyer's case is of great interest. Air embolism was not present in his case, because no vessels were opened. In mine there was no embolism. I hope at some future time to be able to tell you more about this. I think nerves may be found following the large pulmonary arteries leading to the right side of the heart which if crushed or clamped suddenly will produce a fatal reflex.

trachea; and also in spite of the fact that others, notably Jackson,<sup>2</sup> interested in bronchoscopic work report that typical lung abscess is rare with the lodgment of foreign bodies even deep in the air passages.

In an attempt to search for the mechanism that would explain postoperative lung abscess, we repeated the experimental introduction of infected materials by way of the trachea. We were unsuccessful as had been our predecessors. This led to the necessity for a different explanation, and, being conversant with the more recent theory that embolism from the wound may well be the cause of other postoperative pulmonary complications,<sup>3</sup> it seemed possible that such a mechanism might well occur in relation to this single group. From the first our experiments were satisfactory, and we have developed a uniformly successful method<sup>4</sup> for the production of lung abscess by freeing septic emboli into the vascular bed.

In the etiologic discussions of the older writers, the relationship that operative measures hold toward the production of lung abscess was not considered. Mention is made of septic emboli causing pulmonary abscess, but these were frequently multiple, constituting a part of the picture of a pyemia which may or may not have been preceded by an operation. That operative procedures play a significant part in the etiologic rôle of lung abscess is now recognized. A summary of the articles dealing with this complication reveals two important facts: (1) the increasing frequency of the condition postoperatively, and (2) the apparent marked increase following tonsillectomy. The increase in frequency is due in part to the increased recognition for which the roentgen ray is in a large measure responsible. The greater percentage after tonsil operations can also be attributed to a more careful anamnesis.

#### FREQUENCY OF OCCURRENCE

Ever since 1912 when Richardson<sup>5</sup> reported the first case of lung abscess following tonsillectomy, the percentage incidence of postoperative lung abscess in the recorded cases has reached a progressively higher figure. The following year one lung abscess was found by Bassim<sup>6</sup> among nineteen pulmonary complications

2. Jackson, C.: Suppurative Diseases of the Lung Due to Inspired Foreign Body Contrasted with Those of Other Etiology, *Surg. Gynec. Obst.* 42:305 (March) 1926.

3. Cutler, E. C., and Hunt, A. M.: Postoperative Pulmonary Complications, *Arch. Surg.* 1:114 (July) 1920; Postoperative Pulmonary Complications, *Arch. Int. Med.* 29:449 (April) 1922. Cutler, E. C.: The Etiology of Postoperative Pulmonary Complications, *S. Clin. N. Amer.* 2:935 (Aug.) 1922.

4. Holman, E.; Weidlein, I. F., and Schlueter, S. A.: A Method for the Experimental Production of Lung Abscess, *Proc. Soc. Exper. Biol. & Med.* 23:266, 1926.

5. Richardson, C. W.: Tonsillectomy with Consideration of Its Complications, *Washington M. Ann.* 12:2, 1912.

6. Bassim: Les Complications broncho-pulmonaires consecutives a l'adenoidectomie et a l'amygdalectomie, Paris thesis, 1913, no. 181.

Dr. Edward W. Archibald, Montreal, presented a paper on "Rating the value of injections of iodized oil, 40 per cent, in diagnosis and pilling the results of treatment."

These papers were discussed by Drs. Frederiek T. Lord, Boston; A. L. Lockwood, Toronto; Franz Torek, New York; Howard Lilienthal, New York; James H. Kernan, New York; Willy Meyer, New York; Carl A. Hedblom, Chicago; David T. Smith, Ray Brook, N. Y.; Jacob J. Singer, St. Louis; Gabriel Tucker, Philadelphia; David H. Ballou, Montreal; Edward W. Archibald, Montreal, and David A. Stewart, Ninette, Manitoba.

#### THURSDAY, SEPTEMBER 30—EVENING

The annual banquet was held in the Ritz Carlton Hotel. Dr. Edward W. Archibald, Montreal, delivered the President's Address.

#### FRIDAY, OCTOBER 1—MORNING

The meeting was continued at the Ritz Carlton Hotel.

Dr. William F. Hamilton, Montreal, by invitation, read a paper on "Nontuberculous Pulmonary Disease." Discussion was opened by Dr. Willis S. Lemon, Rochester, Minn., who was followed by Drs. Frederiek T. Lord, Boston; Howard Lilienthal, New York; Nathan W. Green, New York; Jacob J. Singer, St. Louis; David T. Smith, Ray Brook, N. Y.; Edward W. Archibald, Montreal, and William F. Hamilton, Montreal.

Dr. Carl A. Hedblom, Chicago, read a paper on "Late Results of Thoracoplasty for Bronchiectasis." Discussion was opened by Dr. Howard Lilienthal, New York, who was followed by Drs. Willy Meyer, New York, and Stuart W. Harrington, Rochester, Minn.

Dr. Willis S. Lemon, Rochester, Minn., read a paper on "The Physiologic Effect of Phrenic Neurectomy."

Dr. Howard Lilienthal, New York, read a paper on "The Logical Sequence in Two-Stage Thoracoplasty."

These two papers were discussed by Drs. Edward S. Welles, Saranac Lake, N. Y.; John L. Yates, Milwaukee; Leo Eloesser, San Francisco; Edward W. Archibald, Montreal; Willis S. Lemon, Rochester, Minn., and Howard Lilienthal, New York.

#### FRIDAY, OCTOBER 1—AFTERNOON

The meeting was continued at the Ritz Carlton Hotel.

The association met in executive session to elect new members, elect officers, and consider a revision of the constitution (a draft of the new constitution follows these proceedings), and to transact such other business as should formally come before it.

Dr. Howard L. Beye, Iowa City, read a paper on "Transphrenic Infection: Report of Ten Cases." This paper was discussed by Dr. Edward W. Archibald, Montreal.

Dr. Leo Eloesser, San Francisco, read a paper on "Preliminary Artificial Pneumothorax in Operations on the Open Chest, with Clinical Observations on the Sensibility and Reflexes of Various Parts of the Lung, and Experiences with Various Methods of Anesthesia." Discussion was opened by Dr. Franz Torek, New York, who was followed by Drs. Howard Lilienthal, New York; Willy Meyer, New York; Carl A. Hedblom, Chicago, and Leo Eloesser, San Francisco.



cedure. In Lockwood's<sup>21</sup> series of fifty-three cases, 50 per cent were postoperative. Whittemore's<sup>22</sup> statistics on 100 cases reveal sixty-six (66 per cent) as having been preceded by some operation on the upper respiratory tract. Sante<sup>23</sup> in a serial radiographic study of forty-five cases found six to be postoperative; two followed tonsillectomy and four followed laparotomy. There were four post-operative lung abscesses in the twelve cases studied by Lewald and Green.<sup>24</sup> Lockwood<sup>25</sup> in 1923 compiled 208 cases following tonsillectomy. Homan's<sup>26</sup> study comprises twenty-three cases at the Peter Bent Brigham Hospital. Ten occurred after nose and throat surgery and three following abdominal operations. Heuer and MacCready,<sup>27</sup> in summarizing the sixty-two lung abscesses in the Johns Hopkins Hospital records, found that sixteen occurred after operation, four of which followed tonsillectomy. Glowacki<sup>28</sup> studied ninety cases from a number of St. Louis hospitals during a period of five years. An analysis of only twenty-eight is given. Singer and Graham<sup>29</sup> reported thirty-four cases; eleven (32 per cent) followed an operation. Mackenzie<sup>30</sup> published a report based on 169 cases from Bellevue Hospital, New York, during the years 1918-1922, eleven of which followed tonsillectomy. The total number following operation is not given. In the hundred cases reported by Lambert and Miller,<sup>31</sup> twenty-five followed operation, thirteen of which followed tonsillectomy. In a large series of 692 cases observed at the Mayo Clinic by Hedblom,<sup>32</sup> 146 (21 per cent) followed an operation. Of these 146 cases forty-eight (33 per cent) occurred after tonsillectomy. Winner<sup>33</sup> reported twenty-two cases; nine were postoperative. In an analysis of 227 cases by Lord,<sup>34</sup> ninety-six (42 per cent) followed a surgical procedure. Greer<sup>35</sup> analyzed

21. Lockwood, A. L.: Abscess of the Lung. *Surg. Gynec. Obst.* 35:461 (Oct.) 1922.

22. Whittemore, W.: The Etiology and Treatment of Nontuberculous Pulmonary Abscess, *Surg. Gynec. Obst.* 38:461 (April) 1924.

23. Sante, L. R.: A Study of Lung Abscess by Serial Radiographic Examination, *J. Radiol.* 4:183 (June) 1923.

24. Lewald, L. T., and Green, N. W.: The Differential Diagnosis Between Tuberculosis and Lung Abscess, *Arch. Surg.* 6:303 (June) 1923.

25. Lockwood, A. L.: Lung Abscess, *Arch. Surg.* 6:314 (Jan.) 1923.

26. Homans, J.: The Etiology and Clinical Features of Lung Abscess, *Boston M. & S. J.* 188:577 (April 19) 1923.

27. Heuer, G. J., and MacCready, P. M.: Lung Abscess, *Arch. Surg.* 6:337 (Jan.) 1923.

28. Glowacki, B. F.: Pulmonary Abscess: A Study of Ninety Cases, *Laryngoscope* 33:153 (Feb.) 1923.

29. Singer, J. J., and Graham, E. A.: A Study of Thirty-Four Cases of Abscess of the Lung, *J. A. M. A.* 81:193 (July 21) 1923.

30. Mackenzie, L. B.: Lung Abscess, *M. J. & Record* 119:191 (Feb. 20) 1924.

31. Lambert, A. V. S., and Miller, J. A.: Abscess of the Lung, *Arch. Surg.* 8:446 (Jan.) 1924. Miller, J. A., and Lambert, A. V. S.: The Treatment of Abscess of the Lung, *Am. J. M. Sc.* 171:81 (Jan.) 1926.

32. Hedblom, C. A.: The Surgical Treatment of Acute Pulmonary Abscess and Chronic Pulmonary Suppuration, *J. A. M. A.* 83:1577 (Nov. 15) 1924.

33. Winner, P. S.: A Study of Twenty-Two Cases of Lung Abscess, *Illinois M. J.* 47:267 (April) 1925.

34. Lord, F. T.: Certain Aspects of Pulmonary Abscess from an Analysis of 227 Cases, *Boston M. & S. J.* 192:785 (April 25) 1925.

35. Greer, A. E.: Lung Abscess: Thirty-Three Cases, *Am. J. M. Sc.* 169:345 (March) 1925.

# **TENTATIVE DRAFT OF CONSTITUTION FOR THE AMERICAN ASSOCIATION FOR THORACIC SURGERY**

## **ARTICLE I.—NAME**

SECTION. 1.—This Association shall be known as the American Association for Thoracic Surgery.

## **ARTICLE II.—OBJECT**

SEC. 1.—The object of the Association shall be to encourage and stimulate investigation and study that will increase the knowledge of intrathoracic physiology, pathology and therapy, to correlate such knowledge and disseminate it.

SEC. 2.—To attain this object, the Association shall hold at least one scientific meeting every year in which free discussion shall be featured; shall publish annually the transactions of that meeting; shall cooperate with other organizations working toward the same end, and shall undertake such other activities as the Council or the Association as a whole may decide.

## **ARTICLE III.—MEMBERSHIP IN CONGRESS**

SEC. 1.—As a component member of the Congress of American Physicians and Surgeons, this Association subscribes to the Constitution and By-Laws of the Congress.

## **ARTICLE IV.—MEMBERSHIP**

SEC. 1.—There shall be four classes of members: Active, Associate, Senior and Honorary. Admission to membership in the Association shall be by election. Membership shall be limited, the limits on the respective classes to be determined by the By-Laws.

SEC. 2.—Membership may be voluntarily terminated at any time by members in good standing. The Council, acting as a Board of Censors, may recommend the expulsion of a member on the grounds of moral or professional delinquency, and submit his name, together with the grounds of complaint, to the Association as a whole at any of the regularly convened meetings, after giving the member so accused ample opportunity to appear in his own behalf.

## **ARTICLE V.—OFFICERS AND GOVERNMENT**

SEC. 1.—The officers of the Association shall be a President, a Vice President, a Secretary, a Treasurer, and five Councilors. These nine officers and councilors shall be the governing body of the Association, and shall have full power to act in all matters, except as follows:

1. They may not alter the initiation fees or annual dues, nor levy any assessments against the membership.
2. They may in no wise change the Constitution or By-Laws.
3. They may neither elect new members nor alter the status of existing members.
4. They may not deplete the principal of the Endowment Fund.

SEC. 2.—Officers and Councilors shall be elected at the annual meeting of the Association, and shall take office on the first day of January, next succeeding. The President and the Vice President shall be elected for a one year term of

tonsillectomies performed at the Mayo Clinic, Hedblom<sup>32</sup> two occurring after the operation. Data obtained from fires sent out by Moore<sup>19</sup> revealed that 202 cases occurred in approximately 450,000 tonsillectomies, an average of one abscess in 2,225. Two lung abscesses were observed by Herb<sup>41</sup> in a series of tonsil and adenoid operations under general anesthesia. In the statistics obtained by Glowacki<sup>28</sup> from a number of St. Louis hospitals one abscess occurred for every 358 tonsillectomies, while Keiper<sup>42</sup> makes the statement that out of every 781 tonsillectomies one lung abscess is encountered. The source of these figures is not given.

Deductions based on this inadequate statistical data would be quite misleading. That the operation of tonsillectomy has aided considerably in increasing the number of postoperative lung abscess cases is unquestionably true, but the condition attains importance only in a large operative series. Many consider the lesion to be a common complication after tonsillectomy, but the combined figures would seem to indicate that this is a mistaken conception. Furthermore, in view of the vast number of tonsil operations performed every year, it is evident that such a complication is rather infrequent.

#### ETIOLOGY

In the previous etiologic discussion of postoperative lung abscess, opinions have been formed chiefly from clinical study and observation, and scant attention has been paid to the experimental work already performed in this particular field. Moreover, the elaboration and application of suitable therapy has thus far received major attention. It is highly desirable that the etiology of any known disease be substantiated by experimental investigation. Laboratory studies designed to contribute something toward a solution of the causative factors of postoperative lung abscess should be of considerable significance, and, from the standpoint of therapy, advantages from such a study may perhaps be efficaciously applied.

Interest in the entire group of postoperative pulmonary complications naturally incited those who were cognizant of the often dire sequelae to propound certain theories explaining the pathways pursued by the causative agent to the lung. Three possible courses along which infection might travel were recognized, viz., (1) by direct lymphatic extension from the operative area; (2) by way of the bronchi from infected material aspirated during or immediately after the operation.

41. Herb, I. C.: Postoperative Lung Complications, *J. A. M. A.* 79:339 (July 29) 1922.

42. Keiper, G. F.: The Tonsil Question Up to Date, *Laryngoscope* 31:777 (Oct.) 1921.

Council divert any of the principal of the Endowment Fund into the current account of the Association.

In the event of the dissolution of the Association, the Endowment Fund shall be distributed among national institutions of the United States and Canada in a proportion equal to the then existing ratio between the numbers of citizens of the two nations who are members of the Association.

#### ARTICLE VIII.—MEETINGS

SEC. I.—The time, place, duration and procedure of the annual meeting of the Association shall be determined by the Council, subject only to the requirements of the Congress of American Physicians and Surgeons, and the provisions of the By-Laws.

SEC. II.—A special meeting of the Association may be called on one month's notice on the written request of fifteen members. The specific purposes of the meeting must be stated in the request and in the official call for the meeting.

SEC. III.—The annual meeting of the Council shall be held during January.

#### ARTICLE IX.—AMENDMENTS

SEC. I.—This Constitution shall in no wise be changed except by a three-fourths vote of the members present at an annual meeting, and further provided that the proposed alteration or amendment shall have been moved and seconded at a previous annual meeting, and that printed copies of the suggested alteration or amendment shall have been circulated among the members, and that the members shall have been specifically advised that such alteration or amendment will be voted upon.

stitutes an argument for the aspiration mechanism. A few investigators, Blake and Cecil<sup>53</sup> and Kline and Winternitz,<sup>54</sup> have succeeded in producing pneumonia experimentally by intrabronchial insufflation but only when a large number of organisms were used. In contrast to these results the researches of Stillman<sup>55</sup> are of interest. Experiments were carried out with mice exposing them to an atmosphere containing cultures of bacteria in the form of fine mist. *Pneumococcus*, *Streptococcus hemolyticus*, *Bacillus influenzae*, and staphylococcus readily penetrated into the lower respiratory tract. Pneumococci usually disappeared within a few hours and gave rise to no infection even if the mice were chilled. The experiments fail to shed any light on the exact mode of natural infection of the lung with pneumococci. "They indicate that even in so susceptible an animal as the mouse other factors than the presence of pneumococci in the lung are necessary for infection."

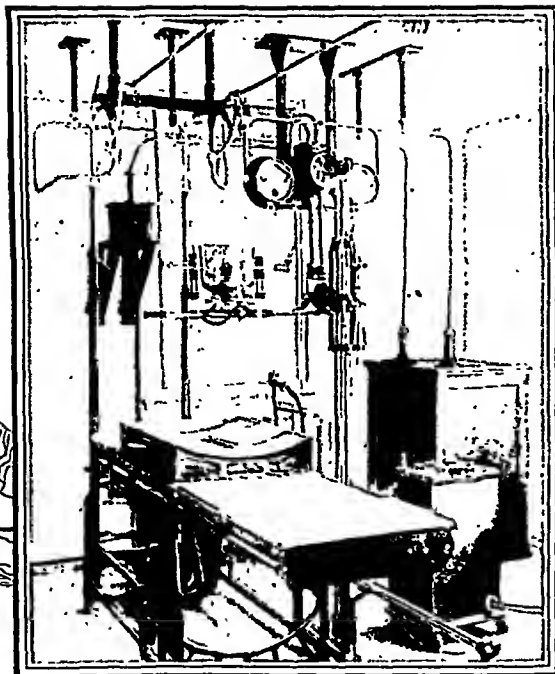
It is difficult to base conclusions on such conflicting evidence, and there remains considerable doubt in the opinion of many that aspiration is the chief cause of postoperative pneumonia. That postoperative lung abscess is the result of aspired infectious material is even more difficult to understand. Here the pathologic lesion is a well circumscribed, limited nidus of infection which continues to enlarge by destroying adjacent parenchymatous tissues, including bronchioles, and finally ruptures into a bronchus adequate in size for its evacuation, or directly into the pleural cavity. As will be shown later, attempts to duplicate lung abscess by intrabronchial measures in animals have proved futile with all investigators. This may be due to the fact that the postoperative lesion was assumed to be a bronchiectatic lung abscess, whereas in reality the condition probably involves originally the parenchymatous tissues and, therefore, has its beginning outside of the bronchial tree. If it could be proved that the process started in this fashion, the manner of its production would be simple. The source of the infection would then obviously have been by way of the blood stream. That lung abscess is derived by such a mechanism can only be proved by accurate pathologic studies through the various evolutionary stages from its incipency. Since this is almost an impossibility in clinical cases, final conclusive evidence will probably never be realized.

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53. Blake, F. G., and Cecil, R. L.: Studies on Experimental Pneumonia: Production of *Pneumococcus* Lobar Pneumonia in Monkeys, *J. Exper. Med.* **31**:403 (Oct.) 1920.

54. Kline, B. S., and Winternitz, M. C.: Studies upon Experimental Pneumonia in Rabbits; The Production of Lobar Pneumonia, *J. Exper. Med.* **21**:304, 1915.

55. Stillman, E. G.: The Presence of Bacteria in the Lungs of Mice Following Inhalation, *J. Exper. Med.* **38**:117 (Aug.) 1923.



Section of X-Ray Department, Anson General Hospital, Iroquois Falls, Ontario, Canada. Installation made by Toronto Branch of Victor X-Ray Corporation.



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the real etiologic factors in postoperative pulmonary complications is further emphasized by Boman<sup>63</sup> and Lockhart-Mummery.<sup>64</sup> Bingold<sup>65</sup> is of the opinion that pulmonary emboli frequently do not display the symptomatology the textbooks teach. There may be only localized pains in the chest followed by hemorrhagic sputum, or the formation of an abscess. Mason<sup>66</sup> in his experimental work on pulmonary embolism and thrombosis states that many of the so-called postoperative pneumonias are embolic processes. Capelle<sup>67</sup> attempts to demonstrate the great frequency of embolism subsequent to operation. He recognizes two types of emboli, the large fatal type and the small type resulting in pleuropneumonic signs which may give rise to a bloody sputum and which usually exhibit pleuritic pain and a friction rub as the first sign. The onset occurs from six to fifteen days after operation, whereas aspiration pneumonia would take place earlier. Similar observations and descriptions of thrombus formation and dislodgment were made by McCann,<sup>68</sup> Ochsner and Schneider,<sup>69</sup> Hampton and Wharton<sup>70</sup> and Rupp.<sup>71</sup> DeQuervain<sup>72</sup> makes this statement:

The most important causes of death—and really three fourths of the true postoperative deaths are due to lung complications—are emboli, pneumonia and lung gangrene. The danger of these complications depends more on the extent of operation than on the question of anesthesia. Even after local anesthesia we have seen embolic processes and pneumonia. Perhaps there will always be an opportunity here to improve our method of procedure. The statistics from our clinic confirm the old conception that a good share of cases which suffer, following

63. Boman, P. G.: Postoperative Pulmonary Complications, *Minnesota Med.* 8:517 (Aug.) 1925.

64. Lockhart-Mummery, P.: Postoperative Pulmonary Embolism, *Brit. M. J.* 2:850 (Nov. 8) 1924.

65. Bingold, K.: Symptoms of Pulmonary Embolism, *München. med. Wchnschr.* 72:1237 (July 24) 1925.

66. Mason, E. C.: Blood Coagulation; the Production and Prevention of Experimental Thrombosis and Pulmonary Embolism, *Surg. Gynec. Obst.* 39:421 (Oct.) 1924.

67. Capelle, W.: Einiges zur Frage der Postoperativen Thromboembolie, *Beitr. z. klin. Chir.* 119:485, 1920.

68. McCann, F.: Suggestions for the Prevention of Postoperative Thrombosis and Embolism, *Brit. M. J.* 1:277 (March 9) 1918.

69. Ochsner, A. J., and Schneider, C. C.: Fatal Postoperative Pulmonary Thrombosis, *Ann. Surg.* 72:91 (July) 1920.

70. Hampton, H., and Wharton, L. R.: Venous Thrombosis, Pulmonary Infarction and Embolism Following Gynecological Operation, *Bull. Johns Hopkins Hosp.* 31:95 (April) 1920.

71. Rupp, A.: Postoperative Thrombosis and Pulmonary Embolism, *Arch. f. klin. Chir.* 115:672 (March) 1921.

72. DeQuervain, E.: A Consideration of the Relative Merits of Resection and Gastro-Enterostomy in the Treatment of Gastric and Duodenal Ulcer, *Surg. Gynec. Obst.* 34:1 (Jan.) 1922.

## POSTOPERATIVE LUNG ABSCESS

AN EXPERIMENTAL STUDY \*

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AND

I. F. WEIDLEIN, M.D.

CLEVELAND

### I. INTRODUCTION

#### TYPES OF LUNG ABSCESS

Pulmonary suppuration, though long a matter of much clinical interest, remains one of the conditions of which the underlying etiologic factors are still in dispute. Several types of lung abscesses seem to occur, each of which may develop from quite different causes. With our present knowledge, classification from the pathologic point of view seems wisest. Aschner<sup>1</sup> groups the several types as follows:

1. Bronchiectasis.
2. Bronchiectatic abscess.
3. Suppurative pneumonitis.
4. Extrabronchial abscess.

Among the more common clinical forms of lung abscess is that which is now recognized as developing subsequent to operation. This recent recognition emphasizes the importance of studying and classifying postoperative lung abscess as a separate clinical entity. The considerable proportion of such abscesses following the operation of tonsillectomy has led the otolaryngologists to study, report on and investigate this condition from both the clinical and laboratory sides. The majority of such reports and investigations conclude that postoperative lung abscess is due to aspiration during the operation. This is in spite of the fact that lung abscess has never been satisfactorily reproduced by the experimental instillation of infected material and foreign bodies by way of the

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\*From the Laboratory of Surgical Research, the Lakeside Hospital and Western Reserve University School of Medicine.

1. Aschner, P. W.: The Pathology of Lung Suppuration, *Ann. Surg.* **75**:321 (March) 1922.



more,<sup>22</sup> Richardson,<sup>80</sup> Tewksbury,<sup>81</sup> Manges,<sup>10</sup> Coakley,<sup>9</sup> Myerson,<sup>82</sup> Hedblom,<sup>32</sup> Pilot and Davis,<sup>83</sup> Glowacki,<sup>28</sup> Chipman,<sup>84</sup> Sante,<sup>23</sup> Meyer,<sup>85</sup> Lemon<sup>48</sup> and Lockwood,<sup>21</sup> base their argument on the following: (1) the common association with general anesthesia; (2) the experimental evidence that aspiration occurs; (3) the high incidence after tonsillectomy and other operations on the upper respiratory tract, and (4) the frequency of lower lobe involvement.

Those who favor embolism, Cutler and Hunt,<sup>3</sup> Homans,<sup>26</sup> Fetterolf and Fox,<sup>86</sup> Porter,<sup>77</sup> Fisher and Cohen,<sup>17</sup> Mackenzie,<sup>30</sup> Lukens,<sup>87</sup> Simpson and Noah,<sup>78</sup> Bevan<sup>88</sup> and Frank,<sup>12</sup> contend that the following facts must be borne in mind: (1) the frequent development after local anesthesia; (2) the high percentage following septic operations or operations performed in potentially infected fields; (3) the greater percentage of occurrence after procedures in mobile operative areas, and (4) the often late development of the symptoms.

The factor of anesthesia and the fact that aspiration occurs have already been sufficiently dwelt on. The comparatively larger number of operations on the upper respiratory tract would naturally predispose to a greater number of pulmonary complications and would, therefore, not constitute a strong argument for the aspiration adherents. We agree with Homans<sup>26</sup> that the aspirating hypothesis is not required to explain the frequency of lower lobe involvement, especially the right. The same percentage holds for lobar pneumonia, infarction, foreign body and embolus localization. The fact that bronchial communications exist with lung abscess is not proof of the aspiratory origin. As the destructive process advances, bronchioles and larger bronchi will gradually be

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80. Richardson, C. W.: Abscess of the Lung and the Method of Prevention in Nasopharyngeal Surgery, *Ann. Otol. Rhin. & Laryng.* **31**:960, 1922.

81. Tewksbury, W. D.: Acute Pulmonary Abscess, *New York M. J.* **110**:849 (Nov. 22) 1919.

82. Myerson, M. C.: Lung Abscess Following Tonsillectomy: A Contribution to the Etiology, *Arch. Otolaryng.* **1**:137 (Feb.) 1925.

83. Pilot, Isadore; and Davis, D. J.: Studies in Fusiform Bacilli and Spirochetes: IX, Their Rôle in Pulmonary Abscess, Gangrene and Bronchiectasis, *Arch. Int. Med.* **34**:313 (Sept.) 1924.

84. Chipman, C. N.: Relation of Anesthetic to Pulmonary Abscess Following Nose and Throat Surgery, *J. A. M. A.* **79**:539 (Aug. 12) 1922.

85. Meyer, Willy: Observations on Lung Suppuration and Its Treatment, *Arch. Surg.* **6**:361 (Jan.) 1923.

86. Fetterolf, G., and Fox, H.: The Reaction of the Paratonsillar Tissues to Tonsillectomy: A Study in the Etiology of Posttonsillectomy Pulmonary Abscess, *Am. J. M. Sc.* **166**:802 (Dec.) 1923.

87. Lukens, R. M.: Pulmonary Abscess Following Tonsillectomy: A Cure by Bronchoscopic Drainage, *S. Clin. N. Amer.* **4**:70 (Feb.) 1924.

88. Bevan, A. D.: Abscess of the Lung—An Important Sequel to Tonsillectomy, *S. Clin.* **2**:921 (Oct.) 1918.

following tonsillectomy and adenotomy. In 1914 Scudder<sup>7</sup> reported sixteen cases of lung abscess treated by surgery. Three occurred postoperatively, one after a nasal septum operation and two after duodenal ulcer operations. The second case of lung abscess following tonsillectomy in American literature was reported by Manges<sup>8</sup> in 1915. The following year Coakley<sup>9</sup> reported a similar case, Manges<sup>10</sup> compiled nine cases and Richardson<sup>11</sup> reported three cases, all occurring after tonsillectomy. In 1917 Frank<sup>12</sup> compiled three such cases and Tewksbury<sup>13</sup> published two cases, one of which followed tonsillectomy and the other a nasal operation. Tewksbury employed artificial pneumothorax and was the first to institute this procedure as a therapeutic measure for the acute abscess. The following year he submitted his results on ten acute abscesses,<sup>14</sup> all following nose and throat operations. From time to time numerous individual cases have been recorded, but only the larger series will be dealt with further.

In a study of 100 cases of lung abscess by Wessler<sup>15</sup> twenty-six followed operation, twenty-one of which were posttonsillectomy. Fifteen additional cases were reported by Wessler and Schwarz,<sup>16</sup> five of which followed tonsillectomy. Fisher and Cohen<sup>17</sup> compiled seventy-six cases after tonsillectomy. Of thirty-eight cases treated by bronchoscopy by Lynah,<sup>18</sup> nine occurred after operation. Moore<sup>19</sup> compiled 202 abscesses occurring in approximately 450,000 tonsillectomies. Prosser<sup>20</sup> found eighteen cases among the records of the medical division of the University of Pennsylvania Hospital, six of which followed some operative pro-

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7. Scudder, C. L.: A Report of the Cases of Lung Abscess at the Massachusetts General Hospital Clinic, Boston M. & S. J. **171**:523, 1914.

8. Manges, M.: Nontuberculous Pulmonary Suppurations, J. A. M. A. **64**: 1554 (May 8) 1915.

9. Coakley, C. G.: Lung Abscess Following Tonsillectomy, Laryngoscope **26**: 1008 (July) 1916.

10. Manges, M.: The Occurrence of Abscess of the Lung After Tonsillectomy, Am. J. Surg. **30**:78 (March) 1916.

11. Richardson, C. W.: Abscess of the Lung Following Operation on the Tonsils and Upper Air Tract, Laryngoscope **26**:1001 (July) 1916.

12. Frank, I.: On Lung Abscess as a Sequel to Tonsillectomy, Laryngoscope **27**:474 (June) 1917.

13. Tewksbury, W. D.: Acute Pulmonary Abscess Treated with Artificial Pneumothorax, J. A. M. A. **68**:770 (March 10) 1917.

14. Tewksbury, W. D.: Treatment of Nontuberculous Lung Abscess with Pneumothorax, J. A. M. A. **70**:293 (Feb. 2) 1918.

15. Wessler, H.: Lung Abscess and Bronchiectasis: A Clinical and Roentgenological Study of 100 Cases, Am. J. Roentgenol. **6**:161 (April) 1919.

16. Wessler, H., and Schwarz, H.: Abscess of Lungs in Infants and Children, Am. J. Dis. Child. **19**:137 (Feb.) 1920.

17. Fisher, L., and Cohen, A. J.: Pulmonary Abscess in Adults Following Tonsillectomy Under General Anesthesia, J. A. M. A. **77**:1313 (Oct. 22) 1921.

18. Lynah, H. L.: Bronchoscopic Studies of Pulmonary Abscess, J. A. M. A. **77**:1548 (Nov. 12) 1921.

19. Moore, W. F.: Pulmonary Abscess: An Analysis of Two Hundred and Two Cases Following Operative Work About the Upper Respiratory Passages, J. A. M. A. **78**:1279 (April 29) 1922.

20. Prosser, W. O. H.: A Review of Eighteen Cases of Pulmonary Abscess, Mil. Surgeon **51**:37 (July) 1922.

TABLE 3.—*Intravenous Injection Series*

TABLE 3.—Intracranial Abscesses							
Experiment	Description of Embolus			Roentgen-Ray Diagnosis of Lesion	Duration of Lesion, Days	Pathologic Description of Specimen	
	Material	Organisms	Location			Gross	Microscopic
16 (Y 5)	Tonsil.....	.....	Right lower lobe	Abscess	5	Large necrotic wallled abscess perforating into bronchus and pleural cavity	Necrotic abscess wall with an adjoining zone of acute diffuse inflammation and densely infiltrated with leukocytes beginning resolution; moderate diffuse acute inflammation
17 (Y 6)	Gelatin capsule containing ton sil and lead	.....	Left lower lobe	Abscess	8	Few pleural adhesions; three small abscesses in lobe	
18 (Y 8)	Gelatin capsule containing ton sil and lead	.....	Left lower lobe	Abscess	31	Large area of fibrosis in lobe surrounding lead filling	Fibrosis of abscess wall; considerable round cell infiltration still present Resolution well established; fibrosis of abscess wall
19 (Y 9)	Gelatin capsule containing ton sil and lead	.....	Left lower lobe	Abscess	11	Small abscess in tip of lobe.....	
20 (Y 9)	Fat, lead.....	.....	Left lower lobe	Abscess	13	Normal	Beginning fibrous tissue formation of abscess walls; considerable cellular exudate still present
21 (Y 10)	Muscle, lead....	Staphylococcus aureus, B. coli	Left lower lobe	Infiltration	19	Two small abscesses containing shot and potato	Resolution beginning; still moderate infiltration
22 (Y 11)	Muscle, metal tube	Staphylococcus aureus	Left lower lobe	None	..	Surface scarring of lobe with an underlying fibrinotic infarct	Necrotic abscess wall with an adjoining zone of acute diffuse inflammation
23 (Y 12)	Potato.....	Staphylococcus aureus	Left lower lobe	Abscess	11	Lobe consolidated and containing large abscess perforating into pleural cavity	Fibrosis of abscess wall; inflammation resolving
24 (Y 13)	Potato, lead shot, muscle	Staphylococcus aureus	Left lower lobe	Infiltration	..	Small abscesses in lobe.....	Still considerable small cell infiltration in wall; fibrous tissue lining lung tissue
25 (Y 14)	Muscle, lead....	Staphylococcus aureus	Left lower lobe	None	8	Small fibrin wallled abscess.....	Inner wall necrotic; surrounding leukocytes
26 (Y 15)	Muscle, lead....	Staphylococcus aureus	Left lower lobe	Abscess	..	Small abscesses in lobe.....	Almost complete fibrotic organization
27 (Y 16)	Tonsil lead....	Staphylococcus aureus (supplementary)	Left lower lobe	None	..	Large necrotic wall abscess.....	
28 (Y 12)	Vein, lead, blood	Staphylococcus aureus	Right lower lobe	Abscess	10	Healed area of fibrosis	
29 (Y 18)	Vein, lead, blood	Staphylococcus aureus, B. coli	Left lower lobe	Abscess	31	Area of fibrosis about lead	
30 (Y 19)	Vein, lead, blood	Staphylococcus aureus, B. coli	Left lower lobe	Abscess	6	Area of fibrosis about lead	
31 (Y 20)	Vein, lead, blood	Staphylococcus aureus, B. coli	Left lower lobe	Abscess	23	Small cavity almost obliterated with fibrosis	Complete fibrinotic healing
32 (Y 21)	Vein, lead, blood	B. coli.....	Left lower lobe	Infiltration	15	Area of fibrosis about lead	
33 (Y 22)	Vein, blood, lead	Staphylococcus aureus, B. coli, streptococcus	Right upper lobe	Consolidation	33	Small cavity almost obliterated with fibrosis	
34 (Y 23)	Vein, blood, lead	Staphylococcus aureus, B. coli, streptococcus	Right lower lobe	Abscess	46	Area of fibrosis about lead	
35 (Y 24)	Vein, blood, lead	Staphylococcus aureus, B. coli, streptococcus	Left lower lobe	Infiltration	..	Area of fibrosis about lead	
36 (Y 25)	Vein, blood, lead	Pneumococcus, streptococcus	Left lower lobe	Consolidation	..	Area of fibrosis about lead	
37 (Y 26)	Vein, blood, lead	Pneumococcus, streptococcus	Left lower lobe	Consolidation	..	Area of fibrosis about lead	

thirty-three cases; twelve (36 per cent) followed operation. In a review of thirty-two cases treated bronchoscopically, Myerson<sup>36</sup> found that ten (31 per cent) followed operation. In a more recent article than that of Hedblom,<sup>32</sup> Lemon<sup>37</sup> stated that fifty-three cases of posttonsillectomy abscess had been observed at the Mayo Clinic. Kernan,<sup>38</sup> in a report before the New York Society for Thoracic Surgery, stated that of the seventy-nine cases treated by him bronchoscopically twenty-five (31 per cent) followed operation. An analysis of the ten cases reported by Eggers<sup>39</sup> reveals two (20 per cent) as having followed operations.

The larger reported series comprising 1,908 cases of lung abscess have been compiled and placed in table 1. Of these 1,908 lung abscesses, 515, or 29.6 per cent, have been classed as postoperative complications,

TABLE 1.—Incidence of Lung Abscess Following Operation

Author	Number of Cases	Following Operation		Number After Tonsillectomy	Per Cent
		Number	Per Cent		
Seudder.....	16	3	19	0	0
Wessler.....	100	26	26	21	21
Wessler and Schwartz.....	15	5	33	5	33
Lynah.....	38	9	23	8	21
Prosser.....	18	6	33	2	11
Lockwood.....	53	23	43	16	30
Whittemore.....	100	66	66	48	48
Sante.....	45	6	13	2	4
Lewald and Green.....	12	4	33	3	25
Homans.....	23	13	57	7	30
Heuer and McCready.....	62	16	26	4	6
Glowacki.....	28	2	7	2	7
Singer and Graham.....	34	11	32	8	24
Mackenzie.....	169	..	..	11	7
Lambert and Miller.....	100	25	25	13	13
Hedblom.....	692	146	21	48	7
Winner.....	22	9	41	7	32
Lord.....	227	96	42	49	21
Greer.....	33	12	36	7	21
Meyerson.....	32	10	31	6	19
Kernan.....	79	25	31	..	..
Eggers.....	10	2	20	1	10
	1,908	515	29.61	268	14.61

an amazing number. It will also be seen that the operation of tonsillectomy contributes in no small measure as a causative factor, being responsible for 14.6 per cent of the total. Statistics vary a great deal regarding the frequency of lung abscess after tonsillectomy. Lyman<sup>40</sup> states that 20,000 tonsillectomies have been performed under nitrous oxide anesthesia in the medical department of Washington University without the development of a single postoperative lung abscess. Out of

36. Myerson, M. C.: The Bronchoscopic Treatment of Lung Abscess, Surg. Gynec. Obst. **41**:573 (Nov.) 1925.

37. Lemon, W. S.: Clinic on Abscess of Lung: Case of Posttonsillectomy Pulmonary Abscess, Arch. Surg. **10**:583 (Jan.) 1925.

38. Kernan, J. A., quoted by Eggers, C.: Lung Abscess Complicated and Hidden by Empyema, Arch. Surg. **12**:338 (Jan.) 1926.

39. Eggers (footnote 38).

40. Lyman, H. W.: Relation of Nose and Throat Operations to Lung Abscess, J. Missouri M. A. **20**:418 (Dec.) 1923.

**Method of Introducing Embolus:** The animal is anesthetized with ether, following the administration of  $\frac{1}{6}$  or  $\frac{1}{4}$  grain of morphine hypodermically. The right jugular vein is exposed and isolated for about 3 cm. Single strands of silk loops weighted with clamps, or bulldog clamps, are placed about the central and distal portions of the exposed vessel to control bleeding. A transverse incision is then made to receive a glass cannula, sufficiently large in diameter to fill the vein lumen. The cannula is connected with rubber tubing to a Luer syringe, and the entire system is filled with salt solution. The material to be injected is then placed into the cannula; the cannula is inserted into the vein; the proximal bleeding control is released, and the embolus is shot into the circulation. To insure passage of the embolus downward the syringe can be filled and emptied several times. The opening in the vein is sutured to reestablish the lumen, or the vessel is merely ligated above and below.

Following the intravenous injection, daily roentgenograms of the chest are taken, and the development of a pulmonary lesion carefully watched for.

**Results.**—In the first few experiments (experiments 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12) various materials were used as emboli, such as pieces of infected tonsillar tissue, bits of muscle and fat impregnated with different bacteria, and in two instances a small cylinder of potato injected with an emulsion of *Staphylococcus aureus*. If such substances, however, are permitted to circulate freely in the blood stream, the bacteria implanted in the bits of tissue can easily become detached and a distribution over a large pulmonary area instead of a concentration at one point will result. In order to prevent the bacteria from being scattered, a small sterile gelatin capsule was used as the conveyor; the infected material was placed into the capsule and the filled capsule injected. The rate of absorption of the gelatin is such that the capsule will not dissolve until lodgment in a pulmonary vessel has taken place. A small bit of paraffinized lead was also included in order that the final resting place of the embolus could be determined by roentgenograms. It was thought that any possible deleterious effect of the metal on the bacteria could be averted if paraffin was used as a coating.

Difficulty was experienced, however, in obtaining gelatin capsules small enough to allow free venous introduction necessary for further promulgation. Their use was therefore abandoned and pieces of muscle and fat tissue were merely folded over a culture of bacteria and the tissue clipped together with a lead filing. In one instance a hole was bored into a small lead shot, bacteria were placed into the hole, and the opening was closed with a bit of muscle tissue. In still another experiment a small metal tube was filled with a bacterial culture, and both ends were closed with muscle.

and (3) by way of the blood stream in the form of septa in the thrombosed vessels of the operative field. In the rapidly accumulating literature dealing with postoperative pneumonia the same views have been applied and repeatedly discussed.<sup>31</sup>

That the lymphatic route is a possibility has been shown by anatomic studies of Sabin<sup>43</sup> and Miller.<sup>44</sup> Not a few writers, especially Clendening,<sup>45</sup> gave this view considerable support. The other views have, however, caused the greatest amount of discussion.

The early investigative work of Hoelscher<sup>46</sup> and Kelly<sup>47</sup> and more recently that of Lemon<sup>48</sup> and Myerson<sup>49</sup> is sufficient experimental evidence that aspiration of oral contents occurs during anesthesia, but the corollary that this means lung infection does not necessarily follow. That aspiration probably occurs in a high percentage of patients undergoing operations under general anesthesia is an accepted fact. If we admit such a possibility, a greater frequency of lung complications should be expected, even in numbers that would exceed the statistics published by Cutler and Hunt.<sup>3</sup> Such is not the case. In spite of badly administered anesthesia, pulmonary complications fail to develop, and in the better clinics where skilled anesthetists are now employed these complications continue to occur.

The presence of specific bacteria has been taken by some investigators as a factor of major importance. Group IV pneumococcus has been found repeatedly in normal mouths<sup>50</sup> and the isolation of these organisms from postoperative pneumonia patients by Whipple<sup>51</sup> and Cleveland<sup>52</sup> con-

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43. Sabin, F. R.: The Method of Growth of the Lymphatic System, Science, New York **44**:145, 1916.

44. Miller, W. S.: Some Essential Points in the Anatomy of the Lung, Am. J. Roentgenol. **4**:269 (June) 1917; The Vascular Supply of the Pleura Pulmonalis, Am. J. Anat. **7**:389, 1908.

45. Clendening, L.: The Cause of Abscess of the Lung After Tonsillectomy, J. A. M. A. **74**:941 (April 3) 1920; Abscess of the Lung, Laryngoscope **32**:128 (Feb.) 1922.

46. Hoelscher, R.: Experimentelle Untersuchungen über die Entstehung der Erkrankungen der Luftwege nach Aethernarkose, Arch. f. klin. Chir. **57**:175, 1898.

47. Kelly, R. E.: Anesthesia by the Intratracheal Insufflation of Ether, Brit. M. J. **2**:112 (July 20) 1912; The Intratracheal Insufflation of Ether, Brit. M. J. **2**:617 (Sept. 14) 1912.

48. Lemon, W. S.: Aspiration: Experimental Study, Arch. Surg. **12**:187 (Jan.) 1926.

49. Myerson, M. C.: Bronchoscopic Observations on the Cough Reflex in Tonsillectomy under General Anesthesia, Laryngoscope **34**:63 (Jan.) 1924.

50. Stillman, E. G.: A Contribution to the Epidemiology of Lobar Pneumonia, J. Exper. Med. **24**:651 (Dec.) 1916.

51. Whipple, A. O.: A Study of Postoperative Pneumonitis, Surg. Gynec. Obst. **26**:29 (Jan.) 1918.

52. Cleveland, M.: Further Studies in Postoperative Pneumonitis, Surg. Gynec. Obst. **28**:282 (March) 1919.

slight pressure so that the embolus can be brought to the desired 3 to 4 mm. diameter. A tight grasp on the ligature is maintained while the needle is withdrawn so that when the end is ligated, bacterial contamination of the exterior is reduced to a minimum. The embolus, resembling a small sausage, is now placed into the open end of the glass cannula and injected (fig. 2).

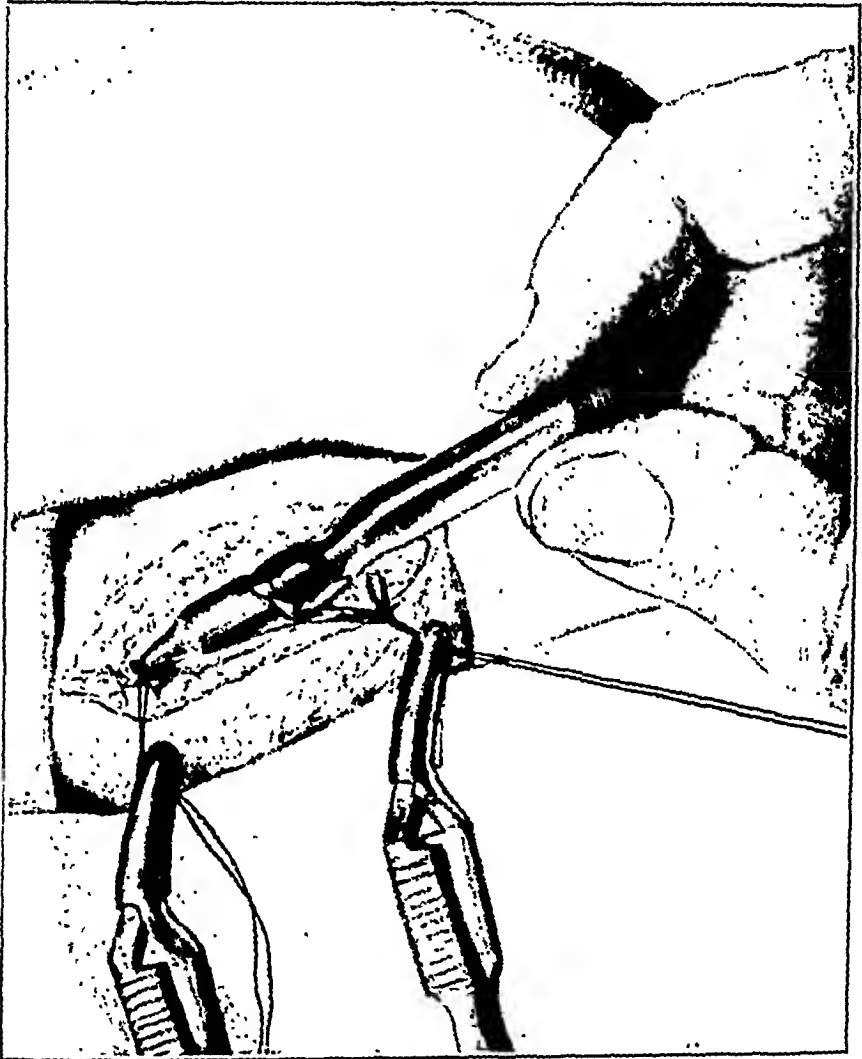


Fig. 2.—Method of introducing septic embolus into jugular vein: A glass cannula with an attached rubber tubing and syringe is filled with salt solution; the embolus is placed into the open end of the cannula, the cannula is inserted into the vein lumen and the embolus is washed into the circulation.

The development of a standard method for the construction and injection of the embolus suggested the possibility of selecting the organism most concerned in abscess formation. The following bacteria were used: *Staphylococcus aureus*, nonhemolytic streptococcus, *Bacillus*

Since a knowledge of the initial pathologic process cannot be obtained in this manner, and in order to show that the production by embolism constitutes a true premise, it is necessary to interpret clinical symptoms and physical signs correctly. Application of these findings in terms of a pathologic process will then furnish sufficient evidence from which justifiable deductions can be drawn as regards the mechanism responsible for the mode of development. If the infective agent is aspired, early or immediate signs and symptoms will be manifested, in all probability during the first postoperative day. Following a variable incremental period coexistent with the abscess, the period of resolution commences either by lysis from gradual absorption or by crisis from rupture and evacuation into a bronchus. If the infective agent is conveyed to the lung by the blood stream, the abscess will begin at a time correspondent with the dislodgment of the embolus from the source of infection. When abscess results in this manner, it follows the operative procedure after a variable length of time, although the breaking loose of a thrombus is usually considered a later event. Symptoms resulting from such a mechanism will of necessity usually exhibit themselves abruptly. There is abundant reference material in the previous writings and numerous case reports which, when carefully studied from a symptomatic point of view, places these lung abscesses in the true parenchymatous class, and they therefore represent lesions resulting from emboli and not from aspiration.

Adequate support of the embolic theory is furnished in a number of early writings, notably those of Otte,<sup>56</sup> Homans,<sup>57</sup> Gebele,<sup>58</sup> Gottstein,<sup>59</sup> Henle<sup>60</sup> and Mikulicz.<sup>61</sup> The latter three authors were able to select a greater percentage of pulmonary complications in patients in whom local anesthesia was employed than in those in whom a general anesthetic was used. Ranzi<sup>62</sup> placed great stress on the frequency of postoperative lung embolism and considered lung infarctions and empyema the result of emboli. The importance of pulmonary embolism and infarction as

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56. Otte, A.: Ueber die Postoperativen Lungen Komplikationen und Thrombosen nach Aethernarkosen, München. med. Wchnschr. 54:2473 (Dec. 10) 1907.

57. Homans, J.: Postoperative Pulmonary Complications, Bull. Johns Hopkins Hosp. 20:128, 1909.

58. Gebele: Ueber Embolische Lungenaffektionen nach Bauchoperationen; Eine klinisch-experimentelle Studie, Beitr. z. klin. Chir. 43:251, 1904.

59. Gottstein, G.: Erfahrungen über lokale Anästhesie in der Breslauer Chirurgischen Klinik, Arch. f. klin. Chir. 57:409, 1898.

60. Henle: Die Methoden der Schmerzbetäubung und ihre gegenseitige Abgrenzung, Verhandl. d. deutsch. Gesellsch. f. Chir. 30:240, 1901.

61. Mikulicz, J.: Die Methoden der Schmerzbetäubung und ihre gegenseitige Abgrenzung, Verhandl. d. deutsch. Gesellsch. f. Chir. 30:560, 1901.

62. Ranzi, E.: Ueber postoperativen Lungenkomplifikationen embolischer Natur, Arch. f. klin. Chir. 87:380, 1908.



*coli* and pneumococcus (table 4). No attempt was made to use bacteria of the same strain and virulence as interest lay chiefly in obtaining a single organism or group of organisms which would invariably cause an abscess. *Staphylococcus aureus* was thought to be most suitable because of certain attributes possessed by this organism, in particular the liquefaction on tissues. In the nine experiments in which *Staphylococcus aureus* was employed as the sole organism, pulmonary lesions failed to develop in four animals. In two other animals infiltration occurred and in only one animal did a true abscess develop. This seemed to indicate that the dog maintains a fairly high resistance to the staphylococcus. The colon bacillus is likewise a tissue liquefier, and in the two experiments in which this organism was used alone an infiltrative lesion developed in one instance without abscess formation, while in the second experiment a lung abscess followed. When these two organisms, however, were combined, lung abscess developed in each of the four animals used. The nonhemolytic streptococcus was responsible in causing two lung abscesses. In a third animal no lesion developed. A pneumococcus was used in three animals without the development of a single lesion. This particular organism had been freshly obtained from a mouse previously inoculated with the sputum from a pneumonia patient. This same organism, however, when combined with *Staphylococcus aureus* and enclosed in the embolus produced an abscess in two out of three animals.

It is evident, therefore, that in the dog a lessened susceptibility exists to any of the foregoing organisms when used singly, and that this is especially true in the case of the pneumococcus and to a lesser extent in the case of the staphylococcus. The colon bacillus and the streptococcus are more apt to produce an infection when used singly. When, however, certain combinations of the organisms are employed, such as a mixture of *Staphylococcus aureus* and *Bacillus coli*, lung abscess will usually result, and if in addition streptococci and pneumococci are introduced into the embolus, the experiments seem to indicate that lung abscess invariably results.

In order to show that emboli may reach the lung from any operative field where the venous channel is unimpeded by valves, we performed two experiments (experiment 55, Dog Y59, and experiment 56, Dog Y60) in which a vein embolus inoculated with cultures of *Bacillus coli* and streptococcus was inserted into the femoral vein. A segment was excised from the distal and smaller portion of the femoral vein; the segment was prepared in the usual manner; the cannula containing the embolus was inserted into the lumen of the central portion of the vein, and the infected embolus was washed into the circulation with salt solution. A lung abscess developed in both animals.

operations upon the stomach, with so-called pneumonia are in reality suffering from a process embolic in nature.

That faults in operative technic, such as infection, careless trans of pedicles, massive ligation of blood vessels and rough use of retract are conducive to pulmonary embolism is pointed out by Heard<sup>73</sup> Delore.<sup>74</sup> Cutler and Hunt<sup>3</sup> have probably contributed more toward better understanding and clearer conception of the importance embolism in postoperative pulmonary complications than any other workers in this field. Their belief that an embolus from the operative field causes the majority of such complications is being corroborated more and more by other observers.

Conclusions have been reached by many writers that the anesthetic employed is of minor importance. In gastric surgery Grégoire<sup>75</sup> has experienced pulmonary complications in 9 per cent of his cases in which local anesthesia was used. Mandl<sup>76</sup> found that after goiter operations lung complications were more frequent after general than after local anesthesia, but that after hernia operations the reverse was true. In Moore's<sup>19</sup> 202 cases of abscess, thirty-nine followed local anesthesia. The two lung abscess cases after tonsillectomy reported by Porter<sup>77</sup> followed local anesthesia. Two similar cases are reported by Simpson and Noah.<sup>78</sup> Metastatic abscesses of the lungs and secondarily of the liver following tonsillectomy under local anesthesia have been observed in three cases at necropsy by Warthin.<sup>79</sup> In the clinics of Gottstein,<sup>59</sup> Henle<sup>60</sup> and Mikulicz<sup>61</sup> there were more lung complications with local than with general anesthesia. It would seem that such evidence strengthens the embolic theory considerably.

Recently there has been considerable discussion concerning the etiologic factors of posttonsillectomy lung abscess. In a census of recent writers, forty declare themselves in favor of aspiration while only ten favor embolism as the direct cause of lung abscess. The most ardent supporters of the aspiration theory, Moore,<sup>19</sup> Lord,<sup>34</sup> Whitte-

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73. Heard, J. E.: Postoperative Pulmonary Embolism, New Orleans M. & S. J. **76**:451 (April) 1924.

74. Delore, X.; Michon, L., and Pollosson, E.: Des Complications Pulmonaires au Cours de la Chirurgie Gastrique, Presse méd. **32**:762 (Sept. 20) 1924.

75. Grégoire, R.: Les Accidents Pulmonaires dans la Chirurgie Gastrique, Bull. et mém. Soc. nat. de Chir. **50**:830, 1924.

76. Mandl, F.: Postoperative Lung Complications, Wien. klin. Wchnschr. **34**: 214 (May 5) 1921.

77. Porter, W. B.: Pulmonary Abscess Following Tonsillectomy Under Local Anesthesia, Virginia M. Monthly **47**:606 (March) 1921.

78. Simpson, J. R., and Noah, H. G.: Report of Two Cases of Lung Abscess Following Tonsillectomy Under Local Anesthesia in Tubercular Subjects, Pennsylvania M. J. **23**:332 (March) 1920.

79. Warthin, A. S., quoted by Frank (footnote 12).

Microscopically, the abscess wall consisted of necrotic tissue with an adjoining zone of acute diffuse inflammation.

**EXPERIMENT 17.**—Dog Y6, weighing 18.8 Kg., July 24, 1925, was given one-fourth grain of morphine. Under ether anesthesia, the right jugular vein was exposed and opened transversely. Bleeding was controlled by single silk strands weighted with clamps. A gelatin capsule filled with tonsil segments and a piece of paraffin coated lead filing was placed into the vessel and forced downward with salt solution. The opening in the vein was closed with silk and the skin was approximated with a continuous subcuticular stitch of silk. A roentgenogram of the chest taken after the operation localized the foreign body in the left lower lobe.



Fig. 4.—Lung specimen obtained at necropsy from Dog Y5, experiment 16, five days after embolism; the right lower lobe contains a large abscess.

July 29, a roentgenogram of the chest showed a large area of density with a well defined central clear area present in the left lower lobe. The respiratory rate was definitely increased.

August 1, the dog was killed in a fight.

**Necropsy.**—There were some recent pleural adhesions existing between the left lower lobe and the chest wall. The left lower lobe was increased in size and density. The surface presented a reddened area at one point, and section through this area revealed one fairly large abscess. Two small abscesses adjoined the larger one (fig. 5). The walls of the abscesses were roughened and necrotic. Microscopically, the abscess wall showed a rather acute diffuse inflammation of the lung tissue adjoining an area of necrosis. Some fibrous tissue was present, a beginning resolution.

included regardless of whether the abscess originally started intra-bronchially or extrabronchially. The time at which the abscess will rupture into a bronchus of sufficient size for evacuation or directly into the pleural cavity is dependent on its anatomic position. A spontaneous occurrence of the latter two events has been described by Hartwell,<sup>89</sup> and Eggers<sup>30</sup> makes the suggestion that rupture into the pleural cavity may be considered as a favorable outcome. Many writers admit that the aspiration of oral or pharyngeal content is not responsible for the ensuing complication per se but that other contributing factors, such as preexisting lung disease, the irritant action of the anesthetic, old age and debility, play an important part. Myerson<sup>82</sup> concludes that the failure of expulsion resulting from damage to the bronchial and lung elements by previous lung infections is the important factor.

The convincing strength of such arguments must be conceded. Based on reliable experimental and clinical evidence, our convictions, however, lead us to believe that embolism is the chief factor. The experimental demonstration by Fetterolf and Fox<sup>86</sup> that thrombi, frequently septic, exist in the tonsillar sinuses, and that dislodgment can easily occur from muscular action, furnishes logical evidence regarding the etiology of posttonsillectomy lung abscess. Mackenzie<sup>30</sup> expresses similar views. The application of suction and the improvement in the administration of anesthesia has not in his opinion reduced the number of lung abscesses. Bevan<sup>88</sup> makes the statement that during a period of two years at the Presbyterian Hospital, Chicago, he has seen from ten to twelve lung and brain abscesses following tonsillectomy. As an argument in favor of the belief that these are hematogenous in origin, he cites several posttonsillectomy brain abscesses occurring without previous lung abscess. The distinction that posttonsillectomy abscess holds in the group of postoperative lung abscesses can probably be partly accounted for by the fact that the operation is conducted in a potentially infected field and the laying open of the venous sinuses is easily accomplished. Likewise the mobility of the area, similarly present in abdominal operations, is conducive to thrombus dislodgment. The influence that mobility exercises toward the breaking loose of a thrombus is strikingly illustrated by the statistics of Cutler and Hunt,<sup>3</sup> in which it was shown that following epigastric operations pulmonary complications developed in 8 per cent of the cases. Grégoire<sup>75</sup> also witnessed such complications in 9 per cent of his cases following gastric surgery under local anesthesia. The time element is of some importance if the complication develops after four to five days. Aspired infections must manifest themselves early. Pulmonary infections developing after a variable symptom free period cannot be regarded in any other way except as embolic in origin. If

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89. Hartwell, J. A.: Abscess of the Lung, *Ann. Surg.* 72:333 (Sept.) 1920.

September 3, a roentgenogram of the chest showed complete obliteration of the cavity.

September 9, the dog was killed in a fight.

*Necropsy.*—There were numerous wounds covering the entire body. The left pleural cavity contained numerous adhesions binding the left lower lobe to the diaphragm and to the lateral chest wall. There was considerable puckering at the lower pole of the lobe and a thickened area about the size of a walnut could be felt within the lobe. The lung cut with resistance at this point. The lead filing was recovered completely encased in fibrous tissue. Sections for microscopic examination were not taken.

EXPERIMENT 19.—Dog Y9, weighing 12 Kg., Sept. 10, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed and prepared for reception of the embolus in the routine manner. A gelatin capsule loaded with a piece of human tonsil tissue and a paraffinized piece of lead filing was introduced into the lumen of the vein and forced onward with salt solution. The vein was closed with silk and the skin was approximated with a subcuticular stitch of silk. A roentgenogram of the chest revealed the foreign body in the left lower lobe.

September 12, the dog was apparently well. No change from the previous roentgenogram was noted.

September 15, a roentgenogram of the chest disclosed no evidence of lung inflammation.

September 21, there was no evidence of infiltration as shown by the roentgenogram.

September 30, repeated roentgenograms of the chest revealed no evidence of a lung lesion.

EXPERIMENT 20.—Dog Y9, Sept. 30, 1925, was given one-fourth grain of morphine. Under ether anesthesia the left jugular vein was exposed and prepared for the reception of an embolus in the routine manner. A piece of fat removed from the wound was folded over a culture of *Staphylococcus aureus* and *Bacillus coli* and clipped together with a paraffinized lead filing. The material was placed into a glass cannula, the cannula was inserted into the lumen of the vein and the embolus was forced onward with salt solution. The vein was ligated above and below with silk, and the skin was closed with subcuticular silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 2, a roentgenogram of the chest revealed a circumscribed area of beginning density about the lead filing.

October 5, a roentgenogram of the chest showed a greater degree of infiltration with beginning rarefaction immediately surrounding the piece of lead.

October 7, cavity formation about the lead was quite distinct

October 12, cavity formation was marked, but the infiltration in the surrounding lung tissue was of less extent.

October 14, it was decided to remove the lobe and a lobectomy was performed. The specimen showed no surface scarring. There was some increase in size and density. When the lung was sectioned, a small abscess was encountered with some apparent fibrosis of the walls (fig. 6). Microscopically, a section of the abscess wall showed considerable fibrosis. Considerable cellular infiltration, chiefly round cells, was seen in the surrounding lung tissue. Histologically resolution was established.

38 (V 27)	Veln, blood, lend	Staphylococcus aureus	Right lower lobe	Abscess	27	Small abscess cavity in lobe.....	Smooth walled zone of fibrous tissue; almost completely healed
39 (Y 28)	Veln, blood, lend	Staphylococcus aureus	Left lower lobe	None	..	Normul	
40 (Y 29)	Veln, blood, lend	Streptococcus aureus	Left lower lobe	Abscess	23	Small abscess cavity in lobe.....	Smooth walled zone of fibrous tissue; almost completely healed
41 (Y 30)	Veln, blood, lend	Streptococcus aureus	Right lower lobe	Abscess	16	Small abscess cavity.....	Fibrosis of inner wall; process almost healed
42 (Y 31)	Veln, blood, lend	Streptococcus aureus	Left lower lobe	Abscess	23	Small abscess cavity.....	Smoothly lined fibrotic cavity; small fibrous wall only remained; inflammation resolved
43 (Y 32)	Veln, blood, lend	Pneumococcus type II	Right lower lobe	None	15	Area of fibrosis about lend	
44 (Y 33)	Veln, blood, lend	Pneumococcus type II	Right lower lobe	None	19	Area of fibrosis about lend	
45 (Y 34)	Veln, blood, lend	Pneumococcus type II	Right lower lobe	None	14	Area of fibrosis about lend	
46 (Y 35)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right lower lobe	Abscess	22	Multiloculated abscess cavity 2.5 cm. in diameter	Fibrous tissue formation; few round cells present
47 (Y 36)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right lower lobe	Abscess	21	Large abscess in lobe.....	Smooth walled fibrotic cavity; considerable round cell infiltration
48 (Y 37)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Left lower lobe	Infiltration	17	Area of fibrosis about lend	Fibrotic walled cavity; moderate degree of cellular infiltration
49 (Y 38)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right lower lobe	Abscess	16	Small abscess in lobe.....	Moderate degree of cell exudation in wall; some fibrosis
50 (Y 39)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right lower lobe	Abscess	12	Large abscess in lobe.....	Inner wall of abscess necrotic; moderate degree of diffuse inflammation
51 (Y 40)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right lower lobe	Abscess	..	Area of fibrosis about lend.....	Almost healed; dense fibrous tissue formation
52 (Y 41)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Left lower lobe	Abscess	12	Lung collapsed; small abscess perforating into pleural cavity	
53 (Y 42)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Left lower lobe	Abscess	8	Small abscess in lobe	
54 (Y 43)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Left lower lobe	Abscess	4	Large necrotic walled abscess	
55 (Y 44)	Veln, blood, lend	Staphylococcus aureus, pneumococcus type II	Right middle lobe	Abscess	10	Small abscess in lobe	



Fig. 7.—Dog Y10, experiment 21, seven days after embolism; the lead filings can be seen lying at the bottom of an abscess cavity in the left lower lobe.



Fig. 8.—Left lower lobe removed from Dog Y10, experiment 21, thirteen days after embolism; a small abscess cavity is still present. .

The placement of infected materials into the venous circulation in these preliminary experiments demonstrated the comparative ease with which lung abscess could be produced, and the information obtained furnished sufficient evidence to justify further efforts toward constructing more uniform emboli.

The method finally used in preparing the artificial, infected embolus is as follows: The femoral vein is exposed, ligated centrally and distally, and a portion, approximately from 6 to 8 mm. long, utilized for the embolus. A longer strip of vein can be removed so that two or three emboli can be made from the same segment of vein. One end of a

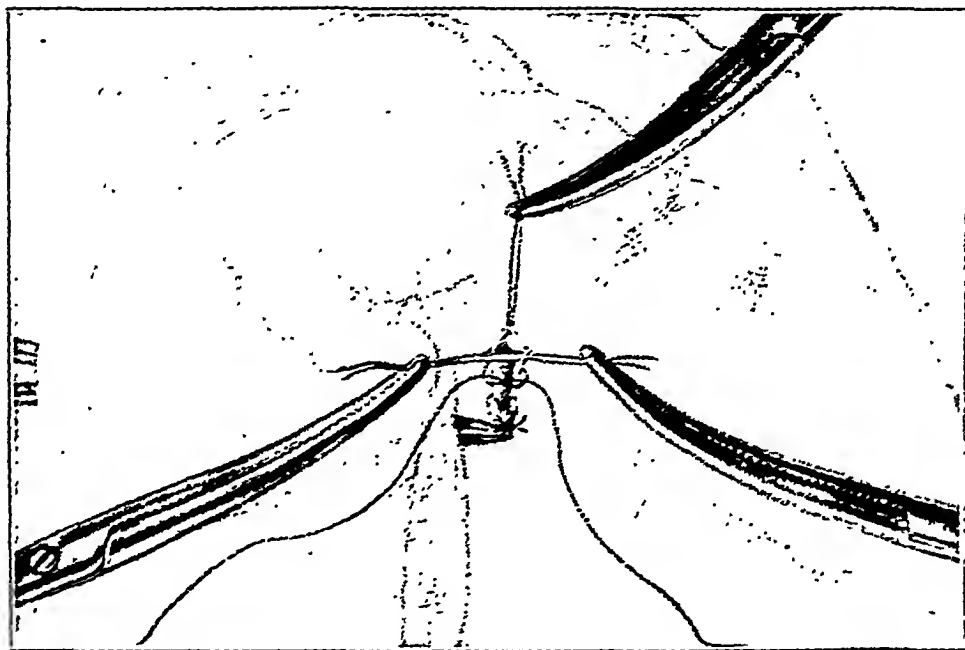


Fig. 1.—Method of preparing vein embolus: One end of the vein segment is closed with a silk ligature; a straight clamp holds this end down firmly; three guy sutures of silk attached to curved clamps serve to hold open the other end of the vein segment; a small bit of lead, bacteria and a few drops of blood can then be introduced; the open end is closed with a ligature of silk.

6 to 8 mm. segment is ligated with silk and held stationary by an attached straight clamp. The other end is held open by three silk sutures as illustrated in figure 1. Into the lumen of this small segment of vein an emulsion of bacteria is introduced by a platinum loop, together with a small bit of lead, previously coated with paraffin so as to render it inert. A few drops of blood are then added with a blunt pointed needle attached to a syringe, the point of the needle being tied in with the silk ligature about the upper end of the vein segment. This is to prevent spilling of infected blood and to enable the production of



circulation. The vein was closed with silk and the skin approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the lead shot in the left lower lobe.

September 17, a roentgenogram of the chest revealed suggestive infiltration about the lead shot.

September 18, the area of infiltration was quite extensive about the lead shot (fig. 9).

September 19, there appeared beginning cavitation in the center of the dense area.

September 23, the infiltration was subsiding but there was more evidence of cavity formation.



Fig. 9.—Dog Y13, experiment 24, four days after embolism; there is considerable infiltration about the lead shot with suggestive cavity formation.

September 26, the infiltration had largely subsided but the cavity was definitely present. The dog remained well.

September 28, the left lower lobe was removed by operation. On palpation a circumscribed area of increased density could be felt near the tip of the lobe. It seemed to be about the size of a walnut. On section the lead shot was found lying in a small abscess cavity. The small cylinder of potato was also found lying in a small abscess cavity a short distance away (fig. 10). Microscopically, a section taken through the abscess wall showed the lining to be composed of considerable fibrous tissue. Small cell infiltration extended for some distance into the adjoining lung tissue. A cellular exudate could be seen in the smaller bronchi.

EXPERIMENT 25.—Dog Y14, weighing 10 Kg., Sept. 15, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was

TABLE 4.—Incidence of Abscess with Various Organisms

Organism	Experiment	Resultant Lesion
Staphylococcus aureus	21 (Y 10)	Abscess formation on sixth day; still present at necropsy on thirteenth day
	22 (Y 11)	Infiltration on sixth day with subsidence on eighteenth day
	23 (Y 12)	None
	24 (Y 12)	None
	25 (Y 13)	Abscess formation on seventh day; early still present at lobectomy on fourteenth day
	26 (Y 14)	Infiltration beginning on third day with subsidence on eleventh day
	27 (Y 15)	None
	38 (Y 27)	Abscess formation on fifth day; large cavity still present at lobectomy on twenty-fifth day
	39 (Y 28)	None
Streptococcus.....	40 (Y 29)	Abscess formation on fifth day; large cavity still present at lobectomy on twenty-third day
	41 (Y 30)	None
	42 (Y 31)	Abscess formation on tenth day; large cavity still present at lobectomy on twenty-third day
Bacillus coli.....	32 (Y 21)	Abscess formation on fifth day; lesion healed on thirty-first day
	33 (Y 22)	Infiltration beginning on fifth day with subsidence on ninth day
Pneumococcus.....	43 (Y 32)	None
	44 (Y 33)	None
	45 (Y 34)	None
Staphylococcus aureus, B. coli	20 (Y 9)	Abscess formation on fifth day; small fibrotic walled abscess still present at lobectomy on fourteenth day
	29 (Y 18)	Abscess formation beginning on eighth day; small cavity found at lobectomy on tenth day
	30 (Y 19)	Abscess formation on sixth day; small cavity still present at lobectomy on thirty-fourth day
	31 (Y 20)	Abscess formation on fourth day; large cavity still present at lobectomy on sixth day
Staphylococcus aureus, pneumococcus	46 (Y 35)	Abscess formation on fourth day; large cavity present at necropsy on twenty-second day
	47 (Y 36)	Abscess formation on sixth day; large cavity present at lobectomy on twenty-first day
	48 (Y 37)	Infiltration beginning on seventh day; lesion found healed at lobectomy on nineteenth day
Staphylococcus aureus, B. coli pneumococcus	49 (Y 38)	Abscess formation on fifth day; large abscess still present at lobectomy on sixteenth day
	50 (Y 39)	Abscess formation beginning on eighth day; large cavity found at lobectomy on twelfth day
	51 (Y 40)	Abscess formation on fifth day; fibrotic lesion found at lobectomy on thirteenth day
Streptococcus, pneu- mococcus	36 (Y 25)	Slight infiltration beginning on sixth day with subsidence after eight days
	37 (Y 26)	Beginning consolidation left lower lobe on first post-operative day and abscess formation on third day; resolution on eighteenth day
Staphylococcus aureus, streptococcus, B. coli	34 (Y 23)	Consolidation right upper lobe on fifth day with resolution on twenty-fifth day
	35 (Y 24)	Abscess formation on fifth day; small fibrotic walled cavity still present at time of lobectomy on thirty-third day
Staphylococcus aureus, streptococcus, pneu- mococcus, B. coli	52 (Y 48)	Abscess formation on seventh day; resolution complete on fourteenth day
	53 (Y 51)	Abscess formation on seventh day with death from rupture into pleural cavity on eleventh day
	54 (Y 52)	Abscess formation on fifth day; death from rupture into pleural cavity on eighth day
B. coli, streptococcus	55 (Y 59)	Abscess formation on second day; large necrotic walled abscess present at lobectomy on fourth day
	56 (Y 60)	Abscess formation on sixth day; small abscess present at lobectomy on tenth day

EXPERIMENT 26.—Dog Y15, weighing 6.4 Kg., Sept. 16, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was prepared in the usual manner. A piece of muscle removed from the wound was folded about a culture of *Staphylococcus aureus* and clipped together with a bit of paraffinized lead filing. The material was placed into a glass cannula, the cannula was inserted into the vein and the embolus forced onward with salt solution. The vein was ligated and the skin was closed in the usual manner. A roentgenogram of the chest localized the foreign body in the left lower lobe.

September 30, roentgenograms of the chest taken almost daily revealed the absence of any lesion in the lungs.

EXPERIMENT 27.—Dog Y16, weighing 10.2 Kg., Sept. 18, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was



Fig. 11.—Dog Y14, experiment 25, six days after embolism; a large circumscribed area of density can be seen about the piece of lead in the left lower lobe.

prepared in the usual manner. A piece of human tonsil supplemented with cultures of *Staphylococcus aureus* and clipped with paraffinized lead filings was placed into the glass cannula, the cannula was inserted into the vein, and the embolus was forced onward with salt solution. The vein was sutured with silk and the skin was closed in the usual manner. A roentgenogram of the chest revealed the foreign body in the left lower lobe.

September 21, the dog appeared sick and had quite a tremor. When first seen in the morning there was blood in the cage, and examination revealed old blood in both nostrils. There was beginning infiltration in the left lower lobe (fig. 12).

September 23, the dog continued ill and would not eat. The entire left base cast a very dense shadow (fig. 13).

September 26, a roentgenogram of the chest showed a very dense shadow occupying the entire lower half of the left chest (fig. 14). The dog died at noon.

## PROTOCOLS

EXPERIMENT 16.—Dog Y5, weighing 6.5 Kg., July 18, 1925, was given one-fourth grain of morphine. Under ether anesthesia, the right jugular vein was exposed. Bulldog clamps were placed on the vein centrally and distally and the vessel was opened by a transverse incision. A small piece of tonsil was inserted into the vein and the tissue forced downward with salt solution. The opening of the vein was sutured with silk and the skin was closed with a continuous subcuticular silk suture.

July 21, the dog appeared sick and would not eat.

July 22, the dog continued ill. The respiratory rate was definitely increased. A roentgenogram of the chest showed considerable infiltration of the right lower lobe.



Fig. 3.—Dog Y5, experiment 16, five days after embolism; the upper area of the consolidated right lower lobe is less dense and probably indicates the upper limits of the abscess.

July 23, there was a marked degree of dyspnea. Just preceding death a bloody discharge was seen to issue from the nostrils. A roentgenogram of the chest taken before death revealed a consolidated lower right lobe containing areas of lessened density (fig. 3).

*Necropsy.*—The pleural cavity contained a cloudy hemorrhagic fluid. The left lung was normal. The right lower lobe was greatly increased in size, red and firm, and presented a fibrinous exudate on the pleural surface. A necrotic perforation entered what was found to be on section a large irregular necrotic walled abscess cavity filled with a partially organized blood clot (fig. 4). An opening led into a bronchus and blood was seen throughout the entire bronchial tree.



Fig. 14.—Dog Y16, experiment 27, eight days after embolism; the entire left lung casts a dense shadow.



Fig. 15.—Left lower lobe removed at necropsy from Dog Y16, experiment 27, eight days after embolism; a large necrotic walled abscess is present.

EXPERIMENT 18.—Dog Y8, weighing 18 Kg., Aug. 7, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed. Bleeding was controlled in the routine manner; the vein was opened by a transverse incision; a gelatin capsule filled with a paraffinized lead filing and a small piece of human tonsil was inserted into the lumen of the vessel; the capsule was forced on with salt solution and the opening in the vessel was closed with silk. The skin was approximated with the usual subcuticular stitch of silk. A roentgenogram localized the foreign body in the left lower lobe.



Fig. 5.—Lung specimen obtained at necropsy from Dog Y6, experiment 17, eight days after embolism; the left lower lobe contains one large and two small abscesses.

August 11, a roentgenogram of the chest showed a diffuse cloudiness of the left lower lobe with a suggestive area of cavitation about the piece of lead. The dog did not eat his food well.

August 20, a roentgenogram of the chest disclosed an abscess approximately 2 cm. in diameter in the left lower lobe just above the dome of the diaphragm near the hilum. The dog appeared well.

August 26, the dog had apparently overcome his infection. A roentgenogram of the chest still showed a small cavity. The dog was removed to the main kennels.



Fig. 16.—Dog Y18, experiment 29, three days after embolism; there is beginning infiltration about the embolus in the left lower lobe.



Fig. 17.—Dog Y18, experiment 29, five days after embolism; a dense circumscribed area is present about the embolus.

EXPERIMENT 21.—Dog Y10, weighing 6.8 Kg., Sept. 11, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed and prepared for reception of the embolus in the routine manner. A piece of muscle taken from the wound was folded about a culture of *Staphylococcus aureus* and clamped with a piece of paraffinized lead filing. The material



Fig. 6.—Left lower lobe removed from Dog Y9, experiment 20, fourteen days after embolism; a small fibrotic walled abscess still remains.

was then placed into a glass cannula, the cannula inserted into the vein and the embolus forced onward with salt solution. The vein was ligated and the skin approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

September 14, a roentgenogram of the chest showed some density about the foreign body.





Fig. 19.—Dog Y19, experiment 30, nine days after embolism; a well defined abscess cavity is present in the left lower lobe.



Fig. 20.—Left lower lobe removed from Dog Y19, experiment 30, thirty-three days after embolism; a small fibrous walled cavity is still present.

September 16, the dog appeared to be breathing more rapidly. A roentgenogram of the chest disclosed an increasing area of density with an area of rarefaction in the center.

September 18, a cavity formation about 1 cm. in diameter was present. The lead filing had dropped to the bottom of the cavity (fig. 7).

September 21, the dog did not appear very ill, and apparently was combating the infection successfully.

September 24, during the preparation for a lobectomy the dog died from the anesthesia.

*Necropsy*.—A firm mass about the size of a walnut could be felt in the left lower lobe. There were no pleural adhesions. On sectioning the lobe, a small abscess was encountered near the lower pole (fig. 8). Microscopically, a section taken through the abscess wall showed almost complete resolution of the inflammatory process. The lining wall of the abscess showed considerable fibrous tissue formation.

EXPERIMENT 22.—Dog Y11, weighing 6.7 Kg., Sept. 12, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed and prepared for reception of the embolus in the routine manner. A culture of *Staphylococcus aureus* was implanted into a small metal tube, 4 mm. long and 2 mm. in diameter, and both ends of the tube were occluded with bits of muscle removed from the wound. The tube was introduced into the lumen of the vessel and forced onward with salt solution. The vein was ligated with silk and the skin approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

September 14, a roentgenogram of the chest revealed no evidence of a pathologic condition of the lung.

September 18, the roentgenogram disclosed for the first time definite signs of infiltration about the foreign body.

September 21, there was more evidence of infiltration in the area previously described.

September 28, the lung shadow present in the previous roentgenogram had largely subsided. The dog had remained well.

October 1, the lower left lobe was removed by operation. The specimen contained a small mass of fibrous tissue completely encasing the metal tube. No sections for microscopic examination were taken.

EXPERIMENT 23.—Dog Y12, weighing 10.5 Kg., Sept. 14, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed and prepared for reception of the embolus. A cylinder of raw potato was cut with a glass tube and impregnated with a suspension of *Staphylococcus aureus*. The tube was inserted into the lumen of the vein and the embolus was forced onward with salt solution.

September 30, almost daily roentgenograms of the chest were taken but the lung remained clear.

EXPERIMENT 24.—Dog Y13, weighing 15.6 Kg., Sept. 14, 1925, was given one-fourth grain of morphine. Under ether anesthesia the right jugular vein was exposed and prepared for reception of the embolus in the routine manner. A cylinder of raw potato was cut with a glass tube and impregnated with staphylococcus. The tube was inserted into the lumen of the vein and the embolus forced downward with salt solution. A small lead shot, which had been previously drilled into, was filled with a culture of *Staphylococcus aureus*, and the hole in the shot was plugged with a bit of muscle. This was likewise forced into the

October 7, a large circumscribed area of density was present in the left lower lobe.

October 9, a roentgenogram showed a large cavity in the center of the area of density. The lead filing had dropped to the bottom of the cavity (fig. 23). The lobe was removed by operation. The left lower lobe revealed an indurated mass in the center of the lobe. Fluctuation within the mass could be palpated. When it



Fig. 23.—Dog Y20, experiment 31, six days after embolism; a large abscess cavity is present; the lead filings have dropped to the bottom of the cavity.



Fig. 24.—Left lower lobe removed from Dog Y20, experiment 31, six days after embolism; a large necrotic walled abscess is present.

was sectioned an abscess cavity about the size of a walnut was encountered containing necrotic tissue and pus (fig. 24). Cultures taken from the pus revealed staphylococcus and *Bacillus coli*. Microscopically, a section taken through the abscess wall showed the inner wall of the cavity to be made up of fibrin and necrotic tissue. The adjoining lung tissue was densely infiltrated with leuko-

exposed and prepared for reception of the embolus in the routine manner. A piece of muscle taken from the wound was folded about a culture of *Staphylococcus aureus* and clamped with a small piece of paraffinized lead. The bit of muscle was then placed into a glass cannula, the cannula was inserted into the vein and the embolus was forced onward with salt solution. The vein was closed with silk and the skin approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

September 18, a roentgenogram of the chest showed a beginning infiltration about the foreign body.

September 21, the shadow of density in the left lower lobe was quite marked (fig. 11).



Fig. 10.—Left lower lobe removed from Dog Y13, experiment 24, fourteen days after embolism; the cylinder of potato can be seen lying in a small abscess cavity: the adjoining lung tissues are infiltrated.

September 26, the area of infiltration was decreasing but a suggestive area of cavitation was present.

September 29, the lobe was removed by operation. The specimen showed a discolored wedge shaped area near the tip and gave evidence of a healing fibrotic infarct. Some induration could be felt beneath the scar in the lung tissue itself. Section through this area disclosed only fibrous tissue, which completely surrounded the piece of lead. Microscopically, a section taken through the area of infiltration showed the inflammatory process to be resolving. There was some fibrous tissue formation. The active inflammatory process extended for only a short distance into the adjoining lung tissue.



Fig. 25.—Dog Y21, experiment 32, five days after embolism; cavity formation about the embolus is quite distinct.

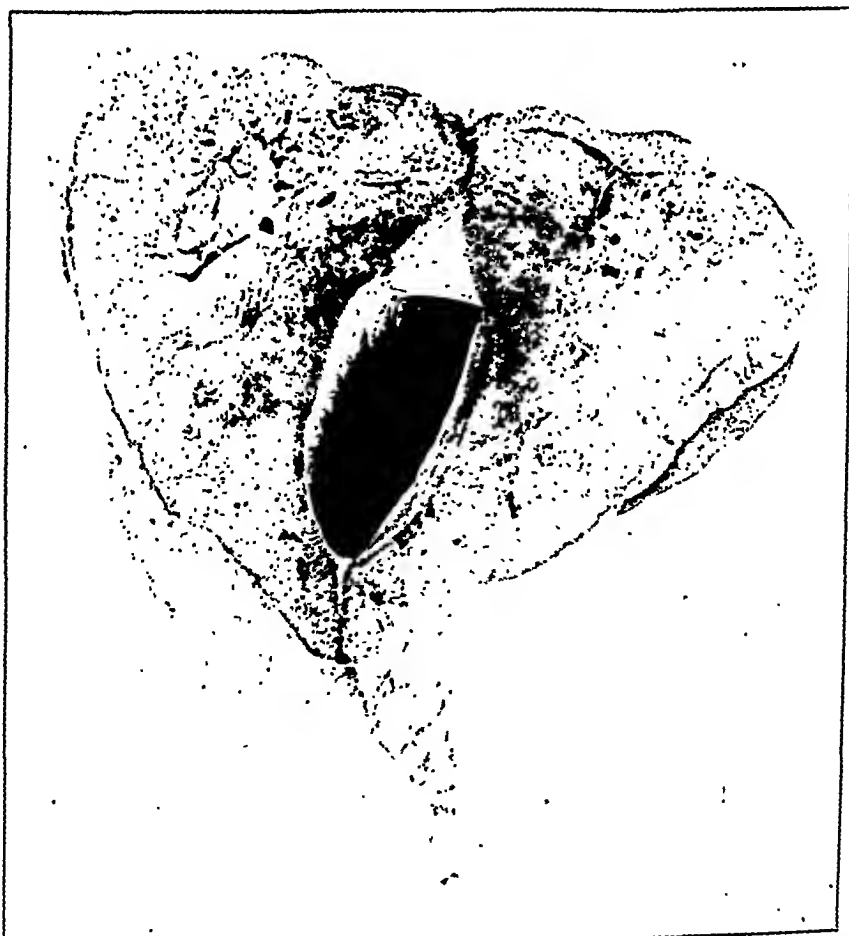


Fig. 26.—Left lower lobe removed from Dog Y21, experiment 32, thirty-three days after embolism; a healed area of fibrosis is present.

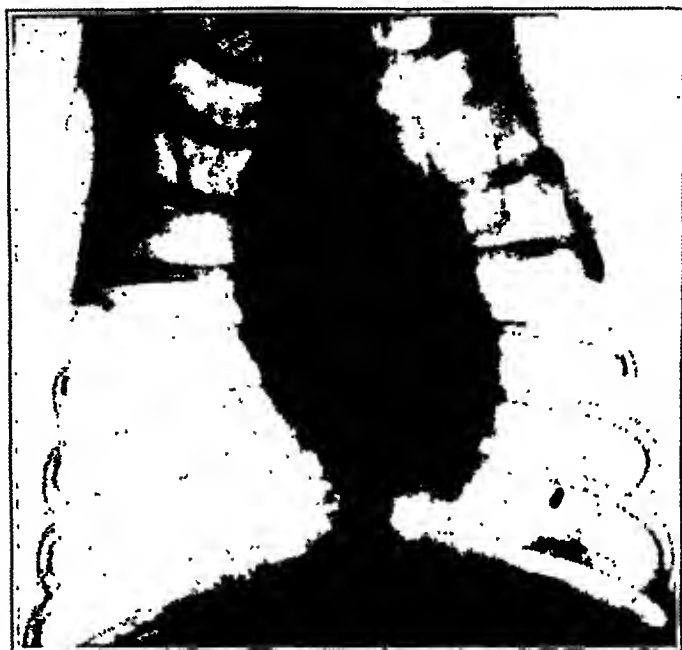


Fig. 12.—Dog Y16, experiment 27, three days after embolism; there is beginning infiltration about the piece of lead in the left lower lobe.



Fig. 13. Dog Y16, experiment 27, five days after embolism; there is marked consolidation of the left lower lobe.



Fig. 27.—Dog Y27, experiment 38, ten days after embolism; a small abscess cavity is visible in the right lower lobe.



Fig. 28.—Right lower lobe removed from Dog Y27, experiment 38, twenty-seven days after embolism; a fibrous lined cavity is still present.

*Necropsy.*—The pleural cavities contained a large amount of dark bloody fluid. There were no pleural adhesions. A large blood clot was present in the left pleural sinus. The entire left lower lobe was large and firm. In the lower part of the lobe an abscess cavity about the size of a walnut was found to have ruptured into the pleural cavity (fig. 15). The upper left lobe showed almost complete atelectasis while the lobes on the right were air containing and apparently normal. Microscopically, a section taken through the abscess wall showed an acute diffuse inflammation of the neighboring lung tissue. The infiltrating cells were mostly leukocytes. The inner wall of the abscess was composed of fibrin and necrotic tissue.

EXPERIMENT 28.—Dog Y12, weighing 10.5 Kg., Oct. 21, 1925, was given one-fourth grain of morphine. Under ether anesthesia the left jugular vein was prepared in the usual manner. The right femoral vein was then isolated and a segment removed. A portion of this segment of vein was prepared according to the technic previously described and inoculated with a pure culture of *Staphylococcus aureus*. The embolus was then placed into a glass cannula and injected into the jugular vein. The skin incisions were closed with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the right lower lobe.

October 23, there was no roentgenographic evidence of infiltration about the foreign body.

October 26, no definite evidence of a pulmonary lesion could be determined.

November 10, the dog remained well and at no time did a pulmonary lesion develop.

EXPERIMENT 29.—Dog Y18, weighing 16.3 Kg., Oct. 2, 1925, was given one-fourth grain of morphine. Under ether anesthesia the left jugular vein was prepared in the usual manner. A segment of femoral vein removed from Dog Y15 was inoculated with cultures of *Bacillus coli* and *Staphylococcus aureus* and injected into the jugular vein. The vessel was closed with silk and the skin was approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 5, a roentgenogram of the chest revealed considerable infiltration about the foreign body in the left lower lobe (fig. 16).

October 7, the infiltration was quite marked and extensive (fig. 17).

October 12, a small area of rarefaction appeared in the central portion of the dense area. It was decided to perform a lobectomy. The dog appeared quite well. Examination of the left lower lobe revealed a fibrotic healed infarct. A small area of induration could be felt within the central portion of the lobe. When the lobe was sectioned a small abscess cavity was encountered (fig. 18). Microscopically, a section taken through the abscess wall showed the inner wall to be made up of fibrous tissue. Histologically, the picture was one of resolving inflammation.

EXPERIMENT 30.—Dog Y19, weighing 16.4 Kg., Oct. 3, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment from the right femoral vein was removed, inoculated with cultures of *Bacillus coli* and *Staphylococcus aureus* and introduced into the left jugular vein. The vessel was sutured with silk and both skin incisions were closed with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 5, there was beginning infiltration about the foreign body.

October 7, infiltration was marked and beginning cavitation was apparent.

October 9, a well defined cavity was present in the roentgenogram.



October 28, there was beginning infiltration about the foreign body.

October 31, a definite abscess cavity could be seen in the left lower lobe.

November 9, the abscess cavity was quite large. The lead filing could be seen in the bottom of the cavity.

November 18, the left lower lobe was removed by operation. The lobe was not bound down by pleural adhesions. A moderately large indurated mass could be felt. When sectioned a fairly large abscess cavity was encountered (fig. 29). Microscopically, a section taken through the abscess wall showed a lining membrane of fibrinous tissue. Histologically, the picture was one of an almost completely healed process.

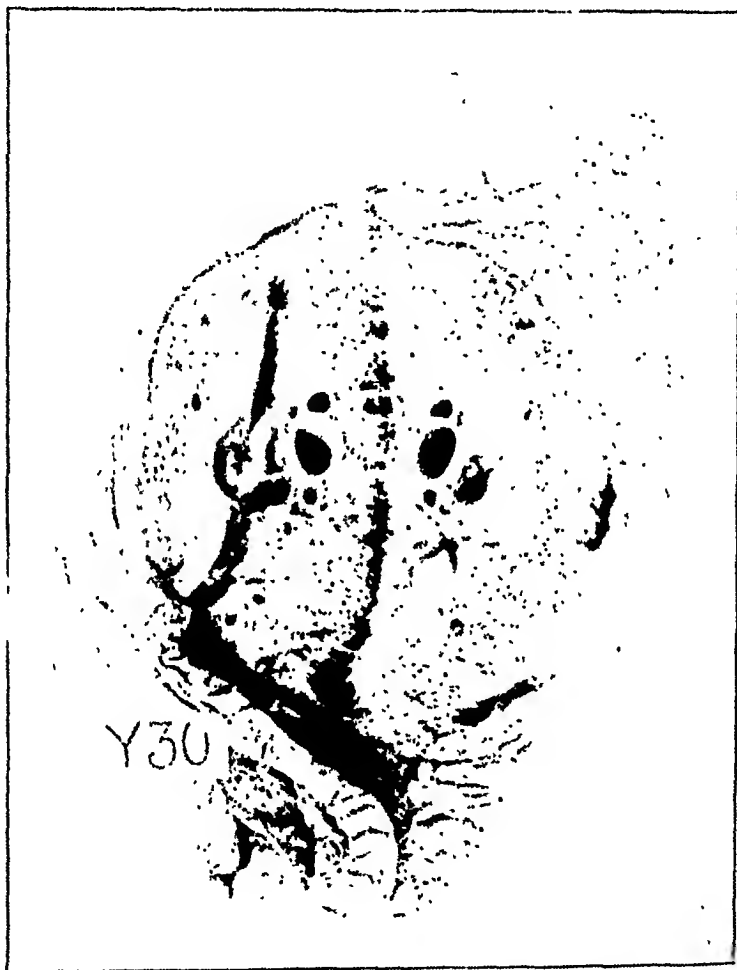


Fig. 30.—Right lower lobe removed from Dog Y30, experiment 41, sixteen days after embolism; a small abscess cavity can be seen.

EXPERIMENT 41.—Dog Y30, weighing 9.5 Kg., Oct. 26, 1925, was given one-sixth grain of morphine. Under ether anesthesia a segment of femoral vein, removed from Y29 and inoculated with cultures of a long chain streptococcus, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 11, the dog failed to show any definite symptoms indicative of an infection. Inability to obtain good roentgenograms on repeated occasions compelled us to remove the right lower lobe by operation in order to ascertain the nature of the lesion. On its external surface the lobe appeared to be normal. Near the tip of the lobe a small abscess cavity was found after sectioning (fig. 30).

October 12, an abscess cavity about 2 cm. in diameter could be seen (fig. 19.)

November 1, roentgenograms of the chest had shown a gradual subsidence of the infiltration. The cavity likewise had decreased in size.

November 6, the left lower lobe was removed by operation. There were numerous pleural adhesions attaching the lobe to the diaphragm. A small area of induration could be felt within the lobe. When it was sectioned a small fibrous walled cavity containing the bits of lead and silk was encountered (fig. 20). Microscopically, a section taken through the abscess wall showed the inner wall of the cavity to be made up almost entirely of fibrous tissue. There was still considerable round cell infiltration.

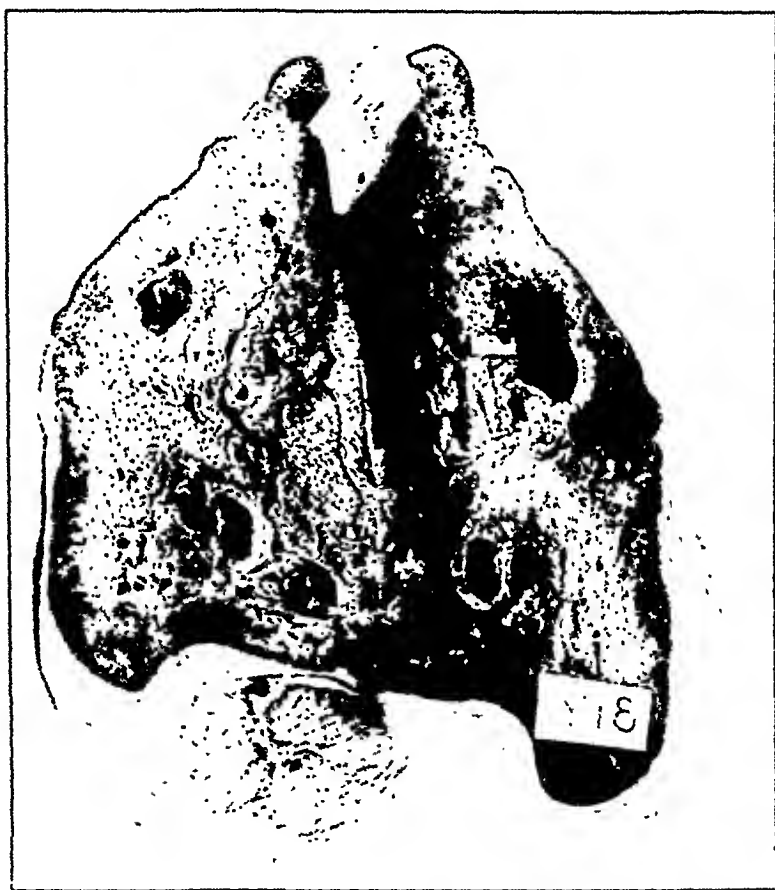


Fig. 18.—Left lower lobe removed from Dog Y18, experiment 29, ten days after embolism; a small abscess cavity containing the piece of lead is still present.

EXPERIMENT 31.—Dog Y20, weighing 10.6 Kg., Oct. 3, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment from the right femoral vein was removed, inoculated with cultures of *Bacillus coli* and *Staphylococcus aureus* and introduced into the left jugular vein. The vessel was sutured with silk and both skin incisions approximated with a subcuticular stitch of silk. A roentgenogram of the chest localized the foreign body in the left lower lobe (fig. 21).

October 5, a roentgenogram of the chest showed considerable infiltration about the foreign body in the left lower lobe (fig. 22).



Fig. 31.—Exterior appearance of the abscess cavity in the left lower lobe removed from Dog Y31, experiment 42, twenty-three days after embolism.

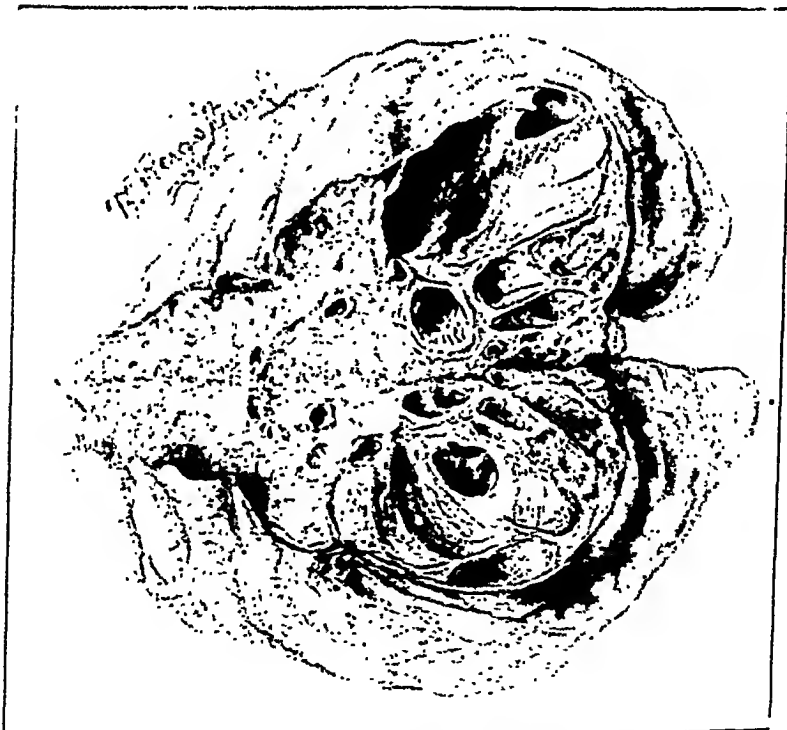


Fig. 32.—Appearance after sectioning the removed lobe of Dog Y31, experiment 42; the multiloculated character of the abscess cavity should be noted.



Fig. 21.—Dog Y20, experiment 31, immediately after embolism; the piece of lead indicates the position of the embolus in the left lower lobe.



Fig. 22.—Dog Y20, experiment 31, two days after embolism; there is beginning infiltration about the embolus.

a fibrotic smooth walled cavity. There was a considerable zone of round cell infiltration.

EXPERIMENT 47.—Dog Y36, weighing 13.2 Kg., Nov. 2, 1925, was given one-grain of morphine. Under ether anesthesia a segment of the right femoral removed, inoculated with cultures of pneumococcus type II and *Staphylococcus*, and introduced into the left jugular vein. A roentgenogram of chest localized the foreign body in the right lower lobe.

November 5, there was beginning infiltration about the foreign body.

November 9, a large cavity could be seen about the foreign body (fig. 34).

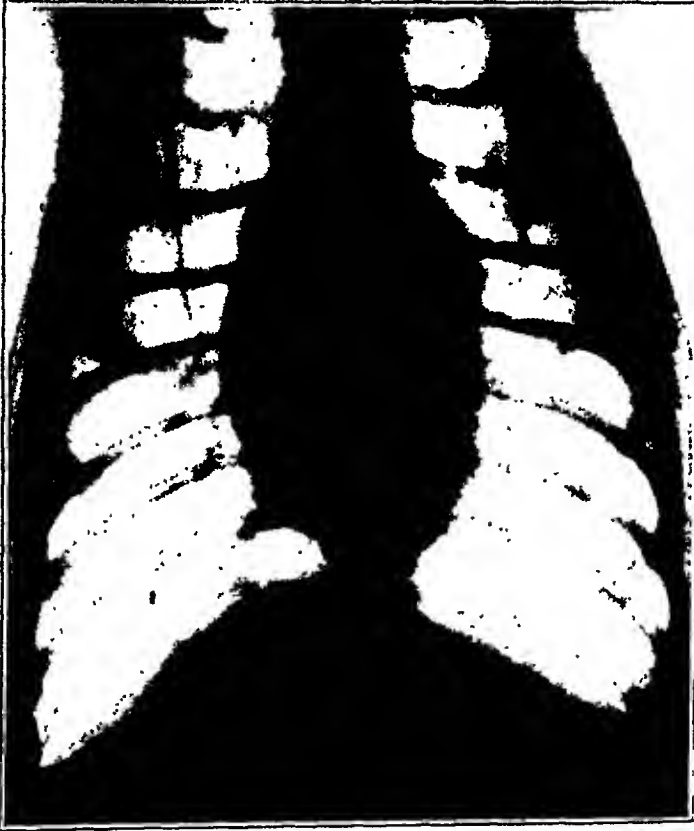


Fig. 34.—Dog Y36, experiment 47, seven days after embolism; a large thin walled cavity without a surrounding lung infiltration can be seen.

November 17, the cavity had increased in size. The dog appeared ill.

November 21, the dog continued ill and showed symptoms of distemper. A roentgenogram revealed a large cavity in the right lower lobe and a diffuse cloudiness in the region of the right middle lobe, evidently the picture of a distemper lung (fig. 35).

November 23, the right lower lobe was removed by operation. A consolidated right middle lobe was also removed. The right lower lobe was definitely increased in size. Induration could be felt within. When sectioned a large abscess cavity was found (fig. 36). Microscopically, a section taken through the abscess wall showed a fairly smooth fibrotic lined cavity. There was a moderate degree of cellular infiltration.

cytes. There was considerable recent hemorrhage. Histologically, the picture was one of acute diffuse inflammation.

EXPERIMENT 32.—Dog Y21, weighing 15 Kg., Oct. 7, 1925, was given one-fourth grain of morphine. Under ether anesthesia a section from the right femoral vein was removed, inoculated with cultures of *Bacillus coli* and introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 8, an area of cloudiness could be seen about the foreign body.

October 12, the area of density was larger in size and a distinct cavity was visible (fig. 25).

November 3, subsequent roentgenograms of the chest revealed a persistence of the cavity.

November 9, the left lower lobe was removed by operation. The specimen showed a healed fibrotic lesion (fig. 26). Microscopic sections were not taken.

EXPERIMENT 33.—Dog Y22, weighing 20 Kg., Oct. 7, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of right femoral vein removed from Y21 and inoculated with cultures of *Bacillus coli* was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 8, there was an area of beginning density about the foreign body.

October 12, considerable infiltration could be seen in the left lower lobe.

October 16, the infiltration had almost subsided.

October 19, a roentgenogram of the chest showed the lungs to be clear.

October 22, the dog was killed in a fight.

Necropsy.—The pleural cavities were free of fluid and adhesions. The lungs were normal except for an area of fibrosis completely encasing the bit of lead. Microscopically the section showed almost complete fibrotic organization. A few round cells were still present.

EXPERIMENT 34.—Dog Y23, weighing 11.3 Kg., Oct. 14, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the right femoral vein was removed, inoculated with cultures of *Bacillus coli*, *Staphylococcus aureus* and streptococcus, and introduced into the right jugular vein. A roentgenogram of the chest localized the foreign body in the right upper lobe.

October 17, a roentgenogram of the chest showed considerable infiltration about the foreign body.

October 19, there was a consolidation of the entire upper right lobe. The dog appeared ill.

October 23, the dog continued ill and would not eat. The right middle lobe appeared consolidated. While the animal was being placed on the roentgen-ray table, considerable bloody and purulent sputum appeared in the nostrils on coughing and sneezing. The infiltration appeared less dense.

October 26, there remained about the same degree of density in the right lung.

October 28, bronchoscopic examination revealed mucopurulent material in the trachea apparently arising from the bronchi on the right side.

October 31, a roentgenogram of the chest showed less density of the right upper lobe. The middle was fairly clear. The dog began to eat better.

November 9, there was almost complete resolution of the pulmonary process.

December 11, the animal was sacrificed.

Necropsy.—There were no pleural adhesions. The lungs appeared normal except for some fibrosis of the right upper lobe. The piece of lead was not visible in an area of fibrosis.

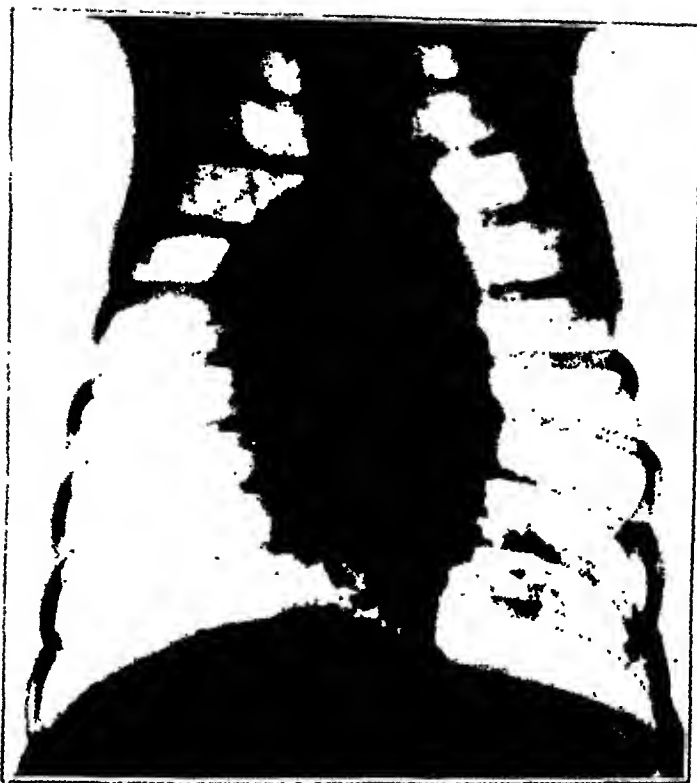


Fig. 37.—Dog Y38, experiment 49, eight days after embolism; an abscess cavity can be seen in the left lower lobe.

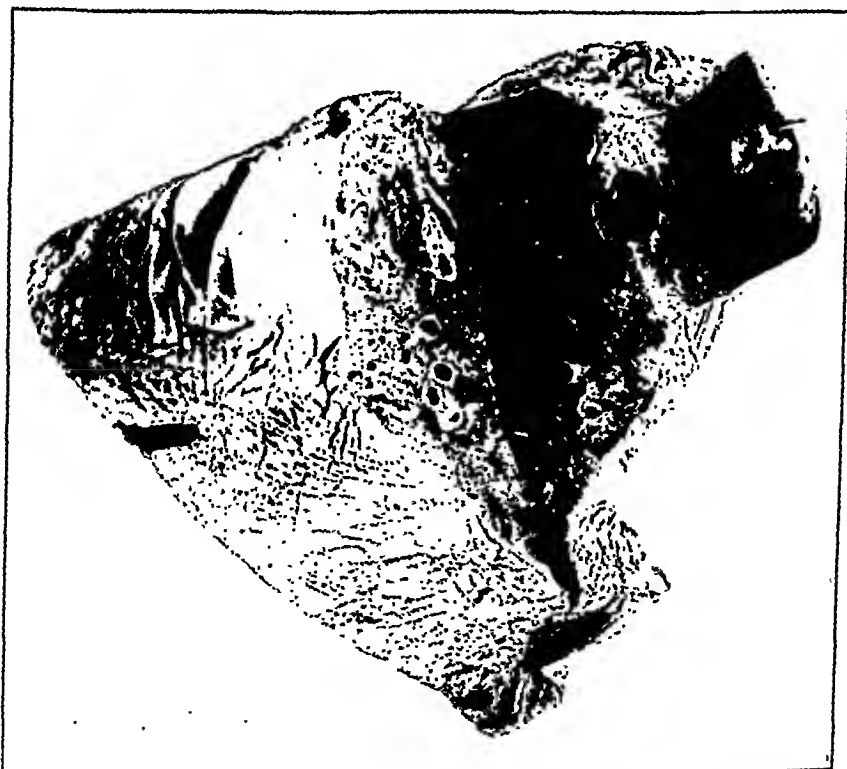


Fig. 38.—Left lower lobe removed from Dog Y38, experiment 49, sixteen days after embolism; a small abscess cavity is still present.

EXPERIMENT 35.—Dog Y24, weighing 13.7 Kg., Oct. 14, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of femoral vein, removed from Y23 and inoculated with cultures of *Bacillus coli*, *Staphylococcus aureus* and streptococcus, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

October 15, a roentgenogram of the chest showed beginning infiltration about the foreign body.

October 17, there was beginning cavitation in the area of density.

November 16, frequent roentgenograms of the chest had shown the persistence of a small cavity in a zone of infiltration in the right lower lobe. It was decided to remove the lobe by operation. The specimen removed showed considerable fibrosis in an area surrounding the lead filing with almost complete obliteration of a small cavity. Microscopically, the section showed complete fibrotic healing.

EXPERIMENT 36.—Dog Y25, weighing 14.5 Kg., Oct. 16, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment was removed from the right femoral vein, inoculated with cultures of pneumococcus and streptococcus, and introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 19, roentgenograms of the chest had not shown any infiltration.

October 22, there was a moderate degree of infiltration about the foreign body.

November 3, the subsequent roentgenograms had shown nothing further and the infiltration had subsided. The dog's general condition remained good.

December 1, the dog was killed in a fight.

*Necropsy.*—Both pleural cavities and lungs were normal. The lead filing was recovered in the left lower lobe encased in a small amount of fibrous tissue.

EXPERIMENT 37.—Dog Y26, weighing 9.5 Kg., Oct. 16, 1925, was given one-sixth grain of morphine. Under ether anesthesia a segment of femoral vein, removed from Y25 and inoculated with pneumococcus and streptococcus, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 17, a roentgenogram of the chest showed a diffuse cloudiness of the left lower lobe.

October 19, density of a moderate degree was confined to the left lower lobe. The dog appeared ill.

October 22, the consolidation was subsiding.

October 27, the lungs were clear. The animal was allowed to live.

EXPERIMENT 38.—Dog Y27, weighing 13.6 Kg., Oct. 21, 1925, was given one-fourth grain of morphine. A segment of femoral vein, removed from Y12 and inoculated with cultures of *Staphylococcus aureus*, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

October 26, a roentgenogram of the chest showed a large area of infiltration about the foreign body with a definite beginning cavitation in the central portion.

October 31, a small abscess cavity in the right lower lobe on a level with the dome of the diaphragm was visible (fig. 27).

November 9, the process had subsided but a small cavity apparently remained with only a slight degree of infiltration surrounding.

November 17, the right lower lobe was removed by operation. A few pleural adhesions existed between the lobe and the diaphragm. Sectioning the lung revealed a large abscess cavity (fig. 28). Microscopically, a section taken through



November 12, there was beginning infiltration about the foreign body

November 14, the infiltration was more marked in extent.

November 16, beginning cavitation was seen within the area of density.

November 19, the infiltration was subsiding. Signs of cavitation had disappeared.

November 24, the infiltration was very slight. The lesion had apparently resolved. The lobe was removed by operation. The removed lobe presented a normal appearance. There was a small area of fibrosis about the lead. Microscopically, the section showed dense fibrous tissue formation. There was still some cellular exudate present.

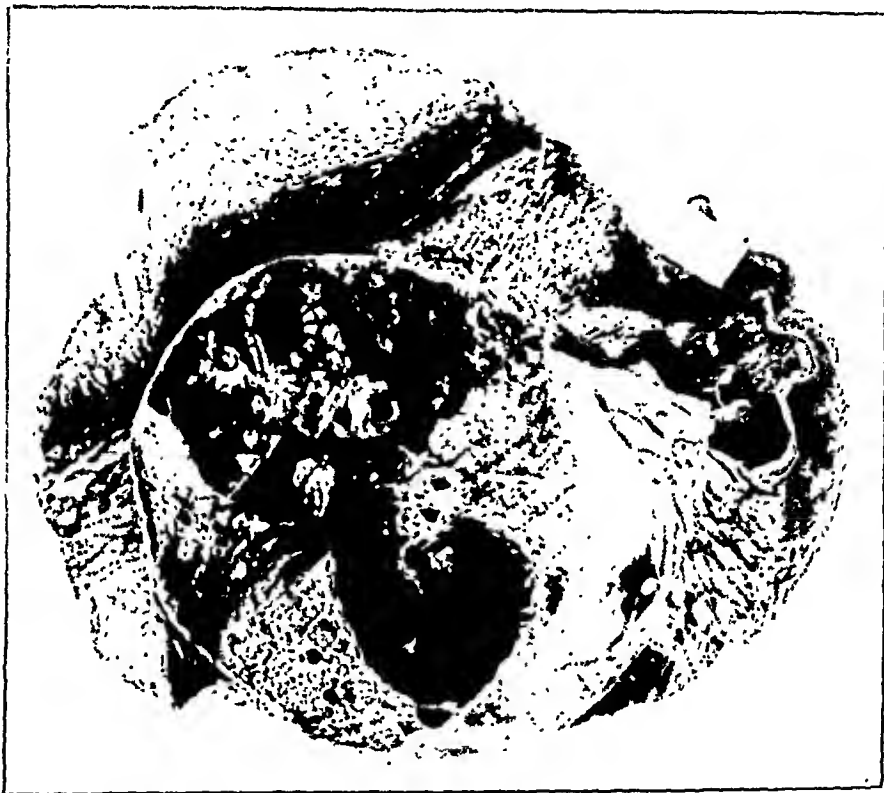


Fig. 39.—Right lower lobe removed from Dog Y39, experiment 50, twelve days after embolism; a large abscess cavity is present.

EXPERIMENT 52.—Dog Y48, weighing 13 Kg., Dec. 14, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the right femoral vein was removed, inoculated with cultures of *Staphylococcus aureus*, *Bacillus coli*, streptococcus and pneumococcus, and introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

December 15, there was beginning infiltration about the foreign body.

December 16, the infiltration was more marked.

December 17, within an increasing area of density beginning rarefaction could be seen.

December 19, the infiltration was subsiding. The signs of cavitation were distinctly visible.

December 21, the lesion was resolving.

Jan. 14, 1926, the lesion had resolved.





Fig. 40.—Dog Y59, experiment 55, one day after embolism; there is beginning infiltration about the embolus.



Fig. 41.—Dog Y59, experiment 55, two days after embolism. There is considerable infiltration of the left lower lobe.

Microscopically, a section taken through the abscess wall showed a fibrous tissue lining with very little cellular infiltration.

EXPERIMENT 42.—Dog Y31, weighing 8 Kg., Oct. 26, 1925, was given one-sixth grain of morphine. Under ether anesthesia a segment of vein, removed from Y29 and inoculated with cultures of a long chain streptococcus, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

October 28, beginning infiltration could be seen about the foreign body.

October 31, the infiltration was more marked.

November 4, a definite multiloculated abscess cavity with a peripheral zone of infiltration was visible.

November 9, the cavity was visible through the apex of the heart shadow. The piece of lead had assumed the most dependent portion of the cavity.

November 18, the abscess persisted in size and the lobe was removed by operation. A definite thin walled cavity could be seen through the visceral pleura (fig. 31). Section through the lesion revealed a multiloculated thin walled cavity. Microscopically, a section through the wall showed a smooth fibrous tissue inner lining (fig. 32). A few round cells were present in the narrow abscess wall. The process was almost healed.

EXPERIMENT 43.—Dog Y32, weighing 13.1 Kg., Oct. 31, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the femoral vein removed from Y33 and inoculated with a culture of pneumococcus type II was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 9, the dog remained well. Daily roentgenograms of the chest revealed no developmental lesion.

November 15, the dog contracted distemper from which he died. Signs of illness preceded death for only a few days.

*Necropsy.*—The lungs and bronchi showed the characteristic distemper findings. There were scattered patches of consolidation throughout both lungs. Pus exuded from the bronchi. The lead filing was encased in a small amount of fibrous tissue.

EXPERIMENT 44.—Dog Y33, weighing 10.1 Kg., Oct. 31, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the right femoral vein inoculated with a culture of pneumococcus type II was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 19, repeated roentgenograms failed to show any developmental lesion, although the dome of the diaphragm always obscured the area occupied by the foreign body. The lobe was removed by operation. The removed lobe was normal. The piece of lead was encased in a slight amount of fibrous tissue. Microscopically the section showed dense fibrous tissue with a few infiltrating round cells.

EXPERIMENT 45.—Dog Y34, weighing 6.2 Kg., Oct. 31, 1925, was given one-sixth grain of morphine. Under ether anesthesia a segment of the femoral vein, removed from Y33 and inoculated with a culture of pneumococcus type II, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 12, repeated roentgenograms disclosed no developmental lesion in the lung.



Fig. 44.—Dog Y60, experiment 56, two days after lodgment of an infected embolus in the right middle lobe; there is beginning infiltration.



Fig. 45.—Dog Y60, experiment 56, five days after embolism; a small abscess cavity surrounded by a zone of infiltration can be seen.

November 14, the dog was killed because of a developing distemper. *Necropsy*.—The typical distemper appearance of the lungs and *hi* was found. The lead filing was encased in fibrous tissue.

EXPERIMENT 46.—Dog Y35, weighing 22.6 Kg., Nov. 2, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the femoral vein, removed from Y37 and inoculated with cultures of pneumococcus type II and *Staphylococcus aureus*, was introduced into the left jugular vein. A roentgenogram of the chest revealed the foreign body in the right lower lobe.



Fig. 33.—Right lower lobe removed from Dog Y35, experiment 46, twenty-two days after embolism; a large abscess cavity is present.

November 5, there was beginning infiltration about the foreign body.

November 12, a small cavity was seen in the zone of infiltration.

November 17, a cavity measuring approximately 2 cm. in diameter could be seen.

November 24, the dog was killed in a fight.

*Necropsy*.—A fairly large indurated mass could be felt in the right lower lobe. When sectioned, an abscess cavity with numerous secondary cavities was encountered (fig. 33). Microscopically, a section taken through the abscess wall showed

March 30, the abscess cavity surrounded by a zone of infiltration had increased considerably in size (fig. 45). The abscessed right middle lobe and the remaining lobes of the right lung were removed by operation. On examining the removed lobe, an indurated mass about the size of a walnut could be felt. The visceral pleura overlying the mass was reddened and thickened. When the lobe was sectioned a small abscess cavity was encountered (fig. 46).

#### COMPARISON AND CONCLUSIONS

From the foregoing protocols it is apparent that we were unable to establish a chronic lung suppuration even in those animals in which the abscess was allowed to remain in the lung for a comparatively long period of time. In Experiments 18, 30 and 32 in which the lesion was examined after thirty-three, thirty-four and thirty-three days, respectively, a healed process was demonstrable. A chronic suppurative process of the lungs will probably never be realized in dogs regardless of the methods employed. The experiences of Scarff<sup>10</sup> help substantiate these conclusions. Drainage of any lung suppuration in the dog is greatly facilitated by nature of the horizontal position assumed by the bronchial tree, but even without such excellent drainage, it is doubtful whether long continued suppuration can be maintained because of the dog's great natural resistive powers.

According to the roentgenograms, the embolus lodged in the left lower lobe in twenty-nine instances and in the right lower lobe in eighteen instances. The reason for such embolus localization is explained by the more direct and straight course pursued by the left pulmonary artery in the dog, and by the characteristic greater volume of blood going to the lower lobes as compared to the upper lobes. In the human being the right pulmonary artery has the advantage over its fellow of the opposite side. In one experiment, the embolus lodged in the right upper lobe and in another the embolus localized in the right middle lobe.

When we briefly review the results obtained, the first experiments demonstrate that lung abscess can probably never be produced in dogs if the infection is introduced by way of the bronchi. The experiments further show that such acute lesions can be produced in dogs if the intravenous route is chosen as the pathway for the transmission of the infective agent to the lung. Successful production is, however, dependent on several factors. Thus, it has been shown that the type of organisms employed is of considerable importance and that certain bacteria must be used in order to produce lung suppuration in the dog. Furthermore, the bacteria must be kept accumulated in a single mass and enclosed in some sort of a capsule to prevent dissemination over a large pulmonary area.

The importance that the physical properties of the embolus hold is strikingly illustrated in the experiments (experiments 16 and 27) in which a covering was not placed about the infected piece of tonsillar

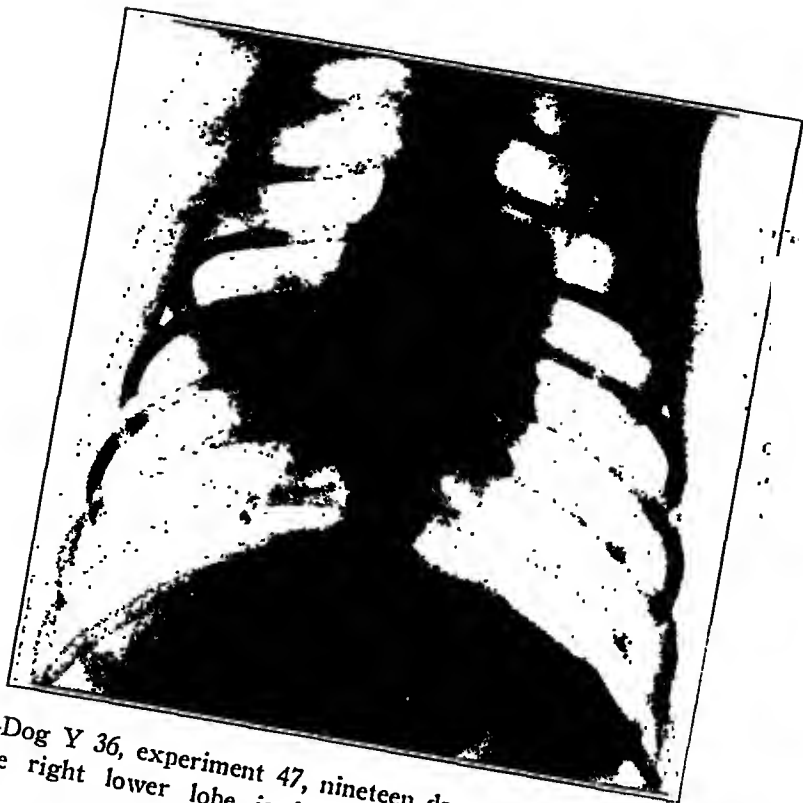


Fig. 35.—Dog Y 36, experiment 47, nineteen days after embolism; the abscess cavity in the right lower lobe is larger; the right middle lobe is densely consolidated.

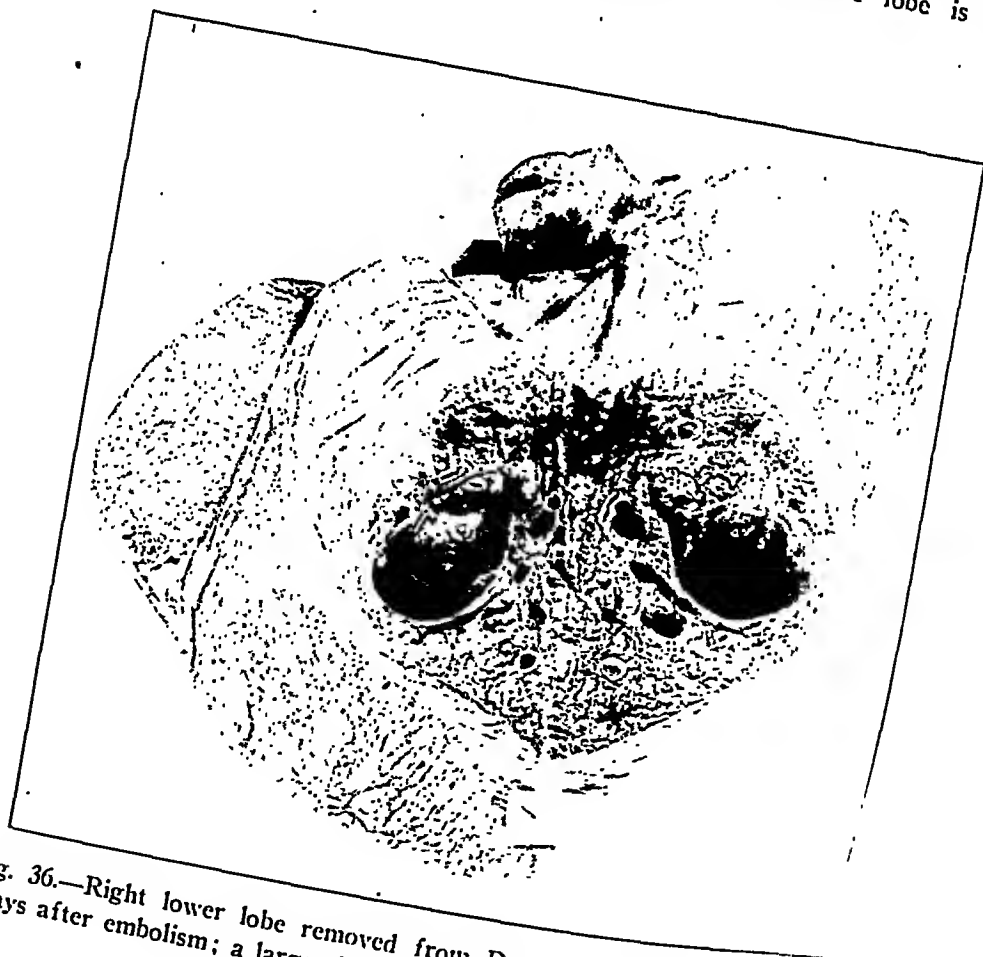


Fig. 36.—Right lower lobe removed from Dog Y36, experiment 47, nineteen days after embolism; a large abscess cavity is present.



TABLE 5.—*Intravenous Injection Series for Pathologic Studies*

Experiment	Description of Embolus		Location	Duration of Lesion	Pathologic Description of Specimen	
	Material	Organisms			Gross	Microscopic
57 (Y 42)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Left lower lobe	1 hour	Embolus lodged in artery	Beginning leukocyte infiltration of arterial wall
58 (Y 41)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Left lower lobe	8 hours	Embolus lodged in artery with beginning thrombosis	Intima of artery destroyed; considerable leukocyte infiltration of lung tissue
59 (X 45)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Right lower lobe	12 hours	Thrombosis of vessels with beginning hemor- rhagic infiltration	Coats of artery densely infiltrated; considerable leukocyte infiltration of lung tissue
60 (X 43)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Right lower lobe	18 hours	Thrombosis and slight infiltration about vessel	Cellular exudate in lumen of vessel; vessel coats difficult to distinguish; early acute inflammation of lung tissue
61 (X 44)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Right lower lobe	24 hours	Thrombosis; infiltration more marked	Vessel wall practically destroyed; marked acute inflammation of lung tissue
62 (X 46)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Left lower lobe	35 hours	Thrombosis; considerable surrounding infiltration	Arterial wall destroyed; pus cells and tissue debris present; surrounding lung tissue, including bronchi, showed acute inflammation
63 (Y 47)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Left lower lobe	2 days	Infiltration marked; beginning area of necrosis in center	Necrotic walled abscess present; surrounding inflammation marked
64 (Y 49)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Left lower lobe	3 days	Large area of infiltration containing small necrotic walled abscess	Extensive acute inflammation
65 (Y 50)	Vein, lead, blood	Pneumococcus, B. coli, streptococcus, Staphylococcus aureus	Right lower lobe	4 days	Same as experiment 64; abscess larger	Marked and extensive acute inflammation

EXPERIMENT 48.—Dog Y37, weighing 18.9 Kg., Nov. 2, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the femoral vein removed from Y35 and inoculated with cultures of pneumococcus type II and *Staphylococcus aureus*, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 5, the lungs appeared normal.

November 9, some infiltration could be seen about the foreign body.

November 13, the dog appeared well. The infiltration remained about the same.

November 19, the infiltration had largely subsided. No cavity formation had appeared. It was decided to remove the lobe by operation. The removed lobe appeared normal. The piece of lead was recovered encased in fibrous tissue.

EXPERIMENT 49.—Dog Y38, weighing 12.1 Kg., Nov. 11, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment was removed from the right femoral vein, inoculated with cultures of *Staphylococcus aureus*, *Bacillus coli* and pneumococcus type II, and introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

November 12, beginning infiltration was apparent about the foreign body.

November 14, infiltration of the left lower lobe was quite marked. Cavitation had appeared in the central portion. The dog appeared slightly ill.

November 19, quite a marked area of cavitation was present (fig. 37).

November 24, cavitation was well marked. The foreign body had dropped to the bottom of the cavity.

November 27, the infiltration had subsided and the cavity had decreased considerably in size. The left lower lobe was removed by operation. In the removed lobe an area of induration could be felt near the tip of the lobe. The visceral pleura was considerably thickened. On section thick indurated lung tissue was encountered. A small abscess cavity was still present (fig. 38). Microscopically, a section taken through the abscess wall showed the lining of the cavity to be composed chiefly of fibrous tissue. There was considerable cell exudation still present.

EXPERIMENT 50.—Dog Y39, weighing 14.8 Kg., Nov. 11, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of the femoral vein, removed from Y38 and inoculated with cultures of *Staphylococcus aureus*, *Bacillus coli* and pneumococcus type II, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

November 13, there was beginning infiltration about the foreign body in the right lower lobe.

November 16, considerable infiltration was present in the right lower lobe.

November 21, a well marked cavity could be seen within the area of density.

November 23, the right lower lobe was removed by operation. The removed lobe was considerably increased in size and an indurated mass could be felt within. Section through this mass revealed a large, necrotic walled abscess (fig. 39). Microscopically, a section taken through the abscess wall showed a fairly smooth fibrous lined cavity containing necrotic and fibrous tissue. There was a moderate degree of diffuse inflammation.

EXPERIMENT 51.—Dog Y40, weighing 17 Kg., Nov. 11, 1925, was given one-fourth grain of morphine. Under ether anesthesia a segment of femoral vein removed from Y38 and inoculated with cultures of *Staphylococcus aureus*, *Bacillus coli* and pneumococcus type II, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the right lower lobe.

*Twelve Hour Specimen.*—Right Lower Lobe: The surface of the lobe appeared normal. A section taken in a plane perpendicular to the bronchus and artery revealed the embolus lodged in an arterial lumen at a point approximately two thirds of the distance from the hilum to the tip of the lobe. The artery lay near a large bronchus. Induration could be felt in the tissues surrounding the vessel and a narrow peripheral zone of hemorrhagic infiltration was visible. The embolus and adjoining thrombus were adherent to the vessel wall. Thrombosis extended distally for a considerable distance but there was no infarction. A section for microscopic examination was taken through and about the area of the embolus. Histologically, all coats of the arterial wall were densely infiltrated with leukocytes. The surrounding lung tissue also showed considerable leukocytic infiltration. Numerous areas of fresh hemorrhage were present. The walls of an adjoining bronchus showed leukocytic infiltration. Some cellular exudate was present in the bronchial lumen.

*Eighteen Hour Specimen.*—Right Lower Lobe: The surface of the lung appeared normal. Section taken through the lobe in a plane perpendicular to the direction of the bronchus and artery revealed the lead and bits of silk within the lumen of the artery at a point about midway between the hilum and the tip of the lobe. There was gross evidence of infiltration and edema in a small area surrounding the point of lodgment of the embolus. Thrombosis extended distally along the lumen of the vessel for a considerable distance. A section for microscopic examination was taken through the area in which the embolus was lodged. Histologically, the lumen of the artery was entirely destroyed. Fibrin, cellular exudate and tissue debris filled the former vessel lumen. The vessel's coats were difficult to distinguish because of the dense infiltration with leukocytes. The inflammatory exudate extended far into the surrounding lung tissue. Numerous areas of fresh hemorrhage were present. An adjoining bronchus was included in the area of inflammation. Histologically, the picture was already that of a true abscess.

*Twenty-Four Hour Specimen.*—Right Lower Lobe: The surface of the lobe appeared normal. A section taken through the lobe in a plane perpendicular to the axis of the bronchus and artery revealed the piece of lead and bits of silk lying within the lumen of the artery about midway between the hilum and the tip of the lobe. Definite thickening could be felt in the tissues surrounding this area. Gross evidence of infiltration and hemorrhage was more marked. A section for microscopic examination was taken through this area. Histologically, bits of silk were seen within the arterial lumen together with considerable cellular exudate and tissue debris. The walls of the artery were still more difficult to distinguish because of the dense infiltration with leukocytes. The adjoining lung tissue was the seat of even more marked inflammation.

*Thirty-Six Hour Specimen.*—Left Lower Lobe: The surface of the lobe appeared normal. An area of density could be felt within lying about midway between the hilum and the tip of the lobe. A section taken through this area traversed the point of lodgment of the embolus. Hemorrhagic infiltration extended radially from this cavity, in which the piece of lead was recovered, for a distance of about 0.5 cm. The vessel wall appeared necrotic. Thrombosis extended distally for a considerable distance. Histologically, the arterial wall was almost completely destroyed. Pus cells and tissue debris occupied the lumen. The abscess wall consisted of leukocytes. Leukocytic infiltration and fresh hemorrhage extended into the surrounding lung tissue. An adjoining bronchus showed destruction of its epithelial lining and in some parts a considerable portion of its entire wall.

EXPERIMENT 53.—Dog Y51, weighing 8.5 Kg., Jan. 13, 1926, was given one-fourth grain of morphine. Under ether anesthesia a segment of right femoral vein was removed, inoculated with pneumococcus type I, *Staphylococcus aureus*, *Bacillus coli* and streptococcus, and introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

January 14 there was beginning infiltration about the foreign body.

January 16, the infiltration was more marked. Beginning cavitation was apparent.

January 21, the dog showed pronounced dyspnea. He appeared to be quite ill. When the chest wall was percussed a hyperresonant note was elicited throughout. A roentgenogram of the chest revealed a collapse of the entire left lung with no evidence of fluid. The abscess had apparently ruptured into the pleural cavity giving rise to a pneumothorax.

January 23, the dog appeared quite well. Signs of pneumothorax were still present. Difficulty was experienced in obtaining good roentgenograms on account of the rapid breathing. There was no evidence of fluid.

January 25, the dog was found dead in his cage.

*Necropsy.*—There was a small amount of pleural fluid. The left lower lobe was bound firmly to the mediastinum near the hilum of the lung. When air was forced into the bronchial tree through the trachea, air could be heard escaping in the region of the adhesions in the left lower lobe. The lungs could not be inflated with air. The lungs were normal, except for an indurated mass in the left lower lobe lying next to the pleural adhesions. Suppurating mediastinal and bronchial glands were found. On section the mass was seen to consist of inflammatory tissue. The abscess cavity had apparently been obliterated from partial rupture into the pleural cavity and mediastinum and the resultant collapse of the lung.

EXPERIMENT 54.—Dog Y52, weighing 6.6 Kg., Jan. 13, 1926, was given one-sixth grain of morphine. Under ether anesthesia a segment of femoral vein, removed from Y51 and inoculated with cultures of *Staphylococcus aureus*, *pneumococcus* type I, *Bacillus coli* and streptococcus, was introduced into the left jugular vein. A roentgenogram of the chest localized the foreign body in the left lower lobe.

January 16, there was considerable infiltration in the area about the foreign body.

January 19, the dog appeared quite ill.

January 21, the dog was found dead in his cage.

*Necropsy.*—Both pleural cavities contained a cloudy hemorrhagic fluid. Numerous pleural adhesions plastered the left lower lobe to the lateral chest wall. An abscess, perforating into the pleural cavity, was found in this lobe. Cultures from the pus recovered the organisms placed into the embolus.

EXPERIMENT 55.—Dog Y59, weighing 13.6 Kg., March 18, 1926, was given one-fourth grain of morphine. Under procain anesthesia the femoral vein was exposed and a portion central to the point of division in the lower leg was removed. The segment of vein was inoculated with cultures of *Bacillus coli* and streptococcus and the prepared embolus was injected into the upper portion of the femoral vein. The vein was ligated and the wound closed with silk sutures. A roentgenogram of the chest localized the foreign body in the left lower lobe.

March 19, the animal appeared ill and would not eat. The rectal temperature was 40.2 C. A roentgenogram of the chest showed a large area of circumscribed infiltration about the piece of lead in the left lower lobe with a beginning central area of rarefaction (fig. 40).

process. Liquefaction of tissue within the inflammatory focus occurs. More and more parenchymatous structures, including bronchial elements, are gradually absorbed. The abscess increases in size and an attempt to halt the destructive forces is made by the production of a surrounding wall of fibrous tissue. If the infection is overcome, healing takes place by scar tissue formation. The rapidity of resolution is dependent on the virulence of the organisms, whether or not evacuation into a bronchus occurs, and on the strength of the resistive powers.

The material dealt with in our study concerns only the extrabronchial or parenchymatous type of lung abscess, and the histologic evidence that a moderately sized bronchus can be destroyed in the early stages of a true abscess has been presented. This would seem to indicate the difficulty of determining from the examination of a chronic lesion whether the abscess was originally an extrabronchial or bronchiectatic lung abscess. In our opinion, the site of the initial infectious process cannot be established by the study of the lesion in a late stage. Histologically, fibrous tissue lined the abscess cavities in the lesions that were permitted to enter into a healing stage. It has been shown<sup>1</sup> that in clinical cases bronchial epithelium at times lines an abscess cavity, but we believe that this process of epithelialization occurs as a later event in the lesions which have become chronic and which communicate with a bronchus. We are unable to furnish experimental evidence, however, which would demonstrate the possibility of an epithelial proliferation from a bronchus into a long standing parenchymatous lung abscess because of our inability to produce a chronic lung abscess experimentally.

## V. GENERAL COMMENT AND CONCLUSIONS

Pathologically, lung abscess consist of two types, bronchiectatic abscess and extrabronchial or parenchymatous abscess. The initial anatomic position assumed by the infecting organisms determines the type that is to follow. Thus the first type originates within the air passages, while the second type begins within the parenchymatous tissues. Each type is entirely dependent on a separate and distinct mechanism by which bacteria are brought to the initial site for implantation. In the parenchymatous abscess this mechanism consists in blood stream transmission of bacteria to the lung while in the bronchiectatic abscess infection is introduced by way of the air passages.

An attempt is made to show that the type of lung abscess developing as a sequel to operation possesses certain distinctive clinical characteristics which when correctly interpreted and defined in terms of a pathologic process place this lung abscess in the true or parenchymatous class, with which no other source of infection than a hematogenous one can be associated.



Fig. 42.—Dog Y59, experiment 55, four days after embolism: there is marked consolidation of the left lower lobe.



Fig 43.—Left lower lobe removed from Dog Y59, experiment 55, four days after embolism, a large necrotic walled abscess is present

The comparatively early formation of a lung abscess, once lodgment of an infected embolus has occurred, and the rapid progress of the destructive lesion illustrates why the condition usually produces such grave clinical symptoms.

A reduction in the number of postoperative lung abscess cases is possible, but the condition can probably never be entirely eradicated. The best prophylactic measures consist of (1) the prevention of infection in the operative field whenever possible; (2) the reduction of operative trauma to a minimum, and (3) the avoidance of mass ligation of tissues.

March 20, the animal continued ill. The rectal temperature was 40 C. A roentgenogram of the chest showed a dense clouding of the entire lower half of the left lung. The heart was pulled over to the left side (fig. 41).

March 22, the animal remained ill. The rectal temperature was 40 C. A roentgenogram of the chest still showed the same degree of lung consolidation (fig. 42). The entire left lung was removed by operation. There were numerous pleural adhesions and the lung was removed with difficulty. The removed lobe was consolidated and over an area of fluctuation the visceral pleura was markedly thickened. When the lobe was sectioned a large necrotic walled abscess was found (fig. 43).

EXPERIMENT 56.—Dog Y60, weighing 13.8 Kg., March 20, 1926, was given one-fourth grain of morphine. Under procaine anesthesia the femoral vein was

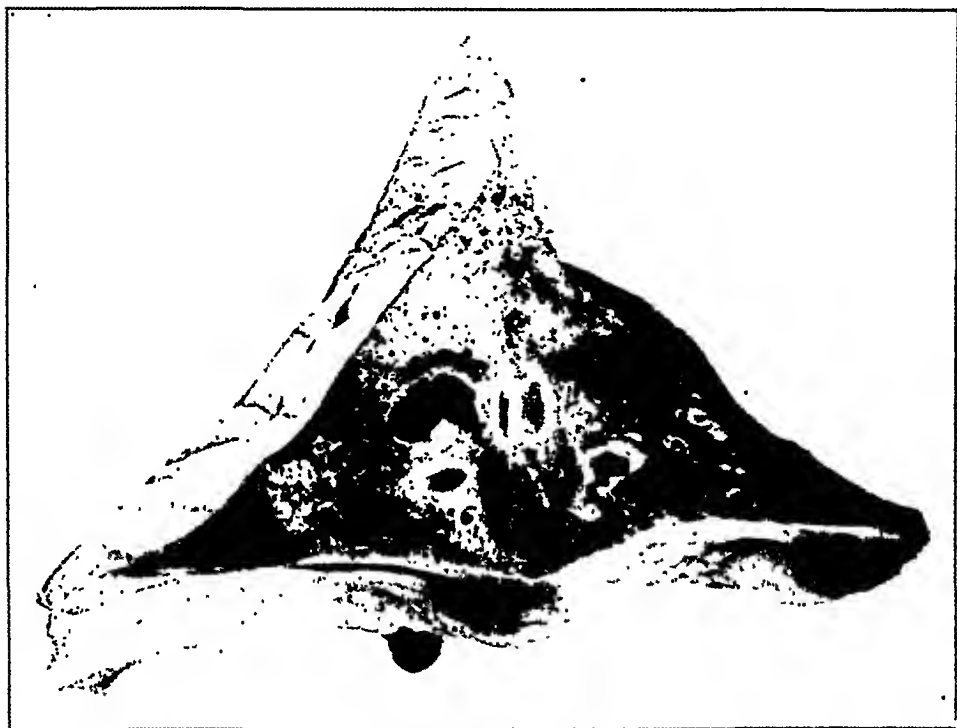


Fig. 46.—Right middle lobe removed from Dog Y60, experiment 56, eight days after embolism; a small abscess cavity is present.

exposed and a portion central to the point of division in the lower leg was removed. The segment of vein was inoculated with cultures of *Bacillus coli* and streptococcus and the prepared embolus was injected into the upper portion of the femoral vein. The vein was ligated and the wound closed with silk sutures. A roentgenogram of the chest localized the foreign body in the left lower lobe.

March 26, six days had elapsed from the date of injection before the embolus localized in the lung. On this date a roentgenogram of the chest revealed the foreign body in the right middle lobe. There was already a slight degree of infiltration about the piece of lead.

March 27, the animal appeared slightly ill but a little food was eaten. A roentgenogram of the chest showed a greater area of density in the right middle lobe (fig. 44). A small cavity appeared within the central area of consolidation.



Cancer cells excite thrombosis and the thrombus as it organizes and contracts destroys them. Cancer in lymphatic vessels, as far as I have seen, excites no such thrombosis, a fact to which Schmidt draws attention. Hence, there is no doubt that although carcinoma often attains access to the blood almost as early as to the lymph, its dissemination takes place almost entirely by the lymphatic and not by the blood vessels.

The practically constant physiologic hyperemia of the bone marrow and the slowing of the blood current within the dilated capillaries, with the adherence of the tumor cells to the endothelium, have been explained<sup>3</sup> as favorable factors for the localization and growth of embolic tumor cells.

#### DISTRIBUTION AND FREQUENCY OF OSSEOUS METASTASES FROM MAMMARY CARCINOMA

Studies of bone metastases have been confined to three fields: First, those associated with spontaneous fractures; second, those found at necropsy, and, third, those observed by roentgen-ray examination. Statistics from these are of little value because of their incompleteness and the inexactitude of the records. Necropsies, which are the most valuable means for such study, rarely extend to a critical examination of the osseous system. Until such structures are universally examined as searchingly as is now done with the lungs and liver, for instance, little will be known as to facts of osseous metastases.

Gross,<sup>4</sup> in 423 compiled necropsies, found secondary tumors in the brain in forty cases, or 9.4 per cent; in the pleura in 178 cases, or 42 per cent; in the liver in 206 cases, or 48.6 per cent, and in the bones in eighty-seven cases, or 20.5 per cent. Paget,<sup>5</sup> in 650 necropsy records of breast cases, found the cranial bones involved thirty-six times, the femur eighteen times and the humerus ten times. Williams,<sup>5</sup> in forty-four necropsies, found the femur affected four times (each once and both twice), the humerus twice (each once), the vertebrae, the tibia and ribs each once. In 893 compiled necropsies, he reported bone metastases in 26.5 per cent of the cases. The percentage site-incidence of these metastases were: cranium, 24; vertebrae, 19.2; ribs, 19.1; femur, 14.5; humerus, 9.3; innominate, 6.5; clavicle, 4.2; scapula, 1.2; leg bones, 0.9; forearm bones, 0.45, and sternum, 0.45. Direct extension of the primary tumor to the ribs, sternum, clavicle and upper end of the humerus was not included in this series.

3. Knox, Leila C.: Relationship of Massage to Metastasis in Malignant Tumors, *Ann. Surg.* **75**:129-142 (Feb.) 1922.

4. Gross, cited by Mann, M. D.: *American System of Gynecology*, Philadelphia, Lea Brothers & Co., 1888, vol. 2, p. 297.

5. Williams, W. R.: *The Natural History of Cancer*, New York, William Wood & Co., 1908, p. 431.

tissue constituting the embolus. In each case a rapidly spreading acute diffuse inflammation developed; a suppurative pneumonitis was produced followed at a later stage by gross necrosis within the affected lung and perforation of the thus formed abscess into the pleural cavity, resulting in death. Similar results were obtained in three experiments in which an infected clot, inoculated with staphylococcus and *Bacillus coli* twenty-four hours previously, was released into the venous circulation. Two of the animals died within forty-eight hours and the third after three days. At necropsy a tremendous infection of the pleura and lung was found. The pathologic process was chiefly limited to the lobe in which the embolus lodged and consisted of an acute diffuse inflammation without gross evidence of tissue destruction.

If the embolus, however, is constructed with a covering, sufficient time is allowed the lung tissues to set up a protective reaction about the point of lodgment of the embolus before the bacteria actually penetrate the lung parenchyma. A well localized inflammatory focus with a peripheral advancing zone of acute inflammation and an increasing central area of necrosis is then gradually permitted to form. Clinically, the embolus consists chiefly of a septic blood clot and in order to conform as nearly as possible with the artificially prepared embolus used in our experiments it must be assumed that the bacteria are in the majority centrally located in a clot that has a somewhat resistant peripheral coat. Should an embolus fail to possess these certain physical properties, a diffuse pneumonitis would be expected such as was produced in the animals in which an infected blood clot was released into the venous circulation. The production of some degree of local tissue immunity made possible by the actual physical make-up of any single infected embolus may play a dominant rôle as to whether lung abscess is or is not to result. Or, we may well hypothecate other methods by which this local immunity is aroused. Thus, in clinical cases one could easily imagine that the organisms to be later transported in abundance in a clot were already being freed in small numbers in the blood stream and thereby setting up a general tissue immunity. Or one could well imagine that smaller, either sterile or infected clots, preceded the major missile and thereby established a specific local tissue immunity in the field in which the larger clot was later to arrive. Certainly, it would appear as if some such problem in tissue immunity was involved.

The fact that abscess occurred in our experiments whether general or local anesthesia was used deserves mention.

#### IV. PATHOLOGIC STUDIES OF EXPERIMENTALLY PRODUCED LUNG ABSCESS

A pathologic study of lung abscess from the incipient to the final stages following the performance of a uniform procedure aimed at production is obviously desirable. It has been shown that lung abscess

bones escape simply because the patient invariably dies before growth has spread along the deep fascia far enough to reach them.

As the result of his work on cancer of the breast, Handley<sup>2</sup> regarded hematogenic embolism as playing an unimportant part in the formation of metastases, and explained all parietal and most visceral metastases as



Fig. 2.—Metastases in occipital, left parietal, vertebral and innominate bones; occipital protuberances destroyed.

being permeations along lymph spaces and fascial planes. Permeation plays an important part in the spread of cancer, especially cancer of the breast; embolism, however, can by no means be disregarded and is, in fact, the only adequate explanation in some cases as in the one reported here.

can be produced by the placement of infected materials into the venous system, and that the lesion is sure to occur with the employment of certain types of organisms in the embolus. With such knowledge at our disposal, examination of similarly produced lesions at various periods of time is possible.

*Method of Collecting Specimens.*—In a series of nine experiments (table 5), a segment of femoral vein was prepared in the usual manner, inoculated with cultures of *Staphylococcus aureus*, pneumococcus, *Bacillus coli* and streptococcus and injected into the jugular vein. Roentgenograms of the chest were made immediately after the injection in order to determine the position of the embolus. The specimens were obtained either by sacrificing the animals or by performing a lobectomy,<sup>92</sup> and the lesions were examined grossly and microscopically after four, eight, twelve, eighteen, twenty-four, thirty-six, forty-eight, seventy-two and ninety-six hours. The lung lobe specimen was injected intrabronchially with formalin (10 per cent) and allowed to remain in the solution for a few days. The lobe was thus brought to the desired normal dimensions present during life.

#### DESCRIPTION OF SPECIMENS

*Four Hour Specimen.*—Left Lower Lobe: The surface of the lung appeared normal. A section taken through the lobe in a plane perpendicular to the main bronchus and artery bisecting the embolus showed blood clot formation within the lumen of the artery. Distally, no infarction was demonstrable. A section for microscopic study was taken transversely through the artery. Histologically, a slight degree of hemorrhage could be seen within the arterial wall and a few leukocytes infiltrated the muscular coat. The intima of the artery was fairly intact throughout. A few leukocytes could be seen in the adjoining lung tissue. The picture was that of a beginning inflammation.

*Eight Hour Specimen.*—Left Lower Lobe: The surface of the lung appeared normal. A section through the lobe in a plane perpendicular to the main bronchus and artery, and at a point midway between the hilum and the tip of the lobe, bisected the embolus plugging the lumen of the artery. A bronchus lay in close proximity. The embolus and surrounding blood clot was already quite adherent to the vessel wall. The thrombus extended distally for about 2 cm. No infarction was demonstrable. A section for microscopic study was taken through the central area of thrombosis and bisecting the embolus. Histologically, the vein, constituting the outer wall of the embolus, could be seen within the lumen of the artery. The intima of the artery was destroyed. There was considerable infiltration of the arterial wall. A few cells could be seen in the surrounding lung tissue. The cells were chiefly leukocytes.

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92. We were led to consider the possibility of operative removal of an abscessed lung because of a desire to preserve the life of the animal. A highly satisfactory technic was evolved, the results of which have been published separately (Schlueter, S. A., and Weidlein, I. F.: *Surgery of the Lung: Experimental Lobectomy and Pneumectomy*, Arch. Surg. 13:459 [Oct.] 1926).

trouble. For weeks she had difficulty in walking, and had found it necessary to depend on support. The day prior to admission to the hospital, in crossing the room supported by a chair which slipped, she felt something "crack" in her thigh, and she fell.

*Physical Examination and Treatment.*—Examination on admission revealed a recent fracture of the left femur, an unhealed fracture of the right humerus, a nodular swelling in the left breast, enlarged left axillary lymph nodes and cystitis. The patient was emaciated and covered with decubitus ulcers; she was of poor intellect and made irrational statements and answers. The blood Wassermann reaction was negative. The blood counts were: erythrocytes, 4,320,000; hemoglobin, 85 per cent; leukocytes, 10,700; neutrophils, 70 per cent; lymphocytes, 15 per cent, and transitionals, 15 per cent. A diagnosis of generalized tuberculosis with bone involvement was made.

The patient remained in the hospital with her extremity in splints and during her stay suffered continuously with pain, especially marked about the frontal region of the head, spine, hips and extremities. Morphine was given regularly but with little relief. During October, the left lower extremity became swollen, and near the end of the month the foot and leg became gangrenous. On November 5, the left leg was amputated at the middle of the thigh. The part amputated was not submitted to pathologic examination. The patient died, Dec. 10, 1925.

*Necropsy.*—The body, that of a well developed, but poorly nourished white woman of 55 to 60 years of age, had been embalmed, and the palpable tissues were fairly firm in consistency. There was a fracture of the right arm at the junction of the lower and middle thirds. Below the point of crepitation was an elliptical firm growth involving the shaft of the bone. There was an angulation with the lower fragment being sharply bent inward. Immediately above the left elbow was a fracture of the left arm. Below the point of crepitation was an irregular, hard mass involving the lower fragment and extending to the elbow. At the junction of the upper two fifths with the lower three fifths of the right thigh was an accidental postmortem fracture. The lower half of the left thigh, leg and foot were absent. At the line of amputation was a recent elliptical, unhealed surgical incision partially closed by sutures. From the edges of the wound exuded a thick, yellow foul smelling pus.

The tissues of the right leg, ankle and foot were edematous. In the posterior thoracic region from the sixth to the eleventh vertebrae, inclusive, the skin, subcutaneous tissues and a part of the muscle tissue were necrosed away, and in this reddish-black area, muscles, ligaments and some of the spinous processes were seen. An oval area covering the prominences of the sacrum was involved in a similar necrotic process. The skin and tissues of the outer surface of the right ankle and side of the foot were necrotic for an area 3.5 by 5 cm. This area was reddish black, and its surface was bathed by a thick, putrid pus. This exudate extended between the bones of the foot, covering their articular surfaces.

Both pleural cavities were largely obliterated by firm white bands of adhesions. The lungs had irregular white, opaque, retracted scars at their apexes. Surrounding these were multiple 1 to 2 mm. firm white tubercles. The heart was of normal size; its chambers contained soft, loose cruor clots. The aorta, the coronary, splenic, renal and pancreatic arteries were thickened, and contained opaque yellow plaques of arteriosclerosis, some of which were calcified.

The spleen, pancreas, liver, gallbladder, bile ducts, suprarenals and the gastrointestinal tract showed no appreciable gross lesions.

The kidneys were normal in size. In the cortex were multiple bilateral yellow to gray abscesses. The tubules appeared as grayish to yellow streaks running to the

*Forty-Eight Hour Specimen.*—Left Lower Lobe: The surface of the lung appeared normal. A small firm nodule could be felt within. A section taken through this area revealed bits of silk and the piece of lead lying within a necrotic arterial wall. Hemorrhagic infiltration extended radially for about 0.5 cm. Distal to this point, the vessel was not thrombosed. Histologically, a small necrotic walled abscess was present. The wall of the abscess consisted of a dense zone of leukocytes. The leukocytic infiltration extended for a great distance into the surrounding lung tissue. Numerous areas of fresh hemorrhage were present throughout. An adjoining bronchial wall was partially destroyed.

*Seventy-Two Hour Specimen.*—Left Lower Lobe: A small mass could be felt within the lobe. The visceral pleura overlying this area was thickened. A section taken through the mass passed through a small abscess cavity about 1 cm. in diameter containing the piece of lead and bits of silk. Necrotic bits of membranous tissue, in all probability the remnants of the vein used as the embolus, were also present. The walls of the artery going to the lobe could be identified lying centrally to the abscess and the vessel on both sides of the abscess cavity was thrombosed. On all sides of the abscess there was a zone of hemorrhagic infiltration approximately 1 cm. in width. The portion of the lung distal to the abscess was quite firm, even to the tip of the lobe. A section for microscopic study was taken through the wall of the abscess. Histologically, the inner wall of the abscess consisted of broken down cells and leukocytes densely packed together. Extensive acute inflammation existed in the surrounding lung tissue.

*Ninety-Six Hour Specimen.*—Right Lower Lobe: The lower half of the lobe was quite firmly consolidated and dark red. The visceral pleura was thickened and covered with a fibrinous exudate. A section taken through the area of consolidation revealed a small abscess cavity from approximately 1 to 2 cm. in diameter, containing bits of silk, the lead filing and necrotic remnants of vein wall. Thrombosis of the artery extended centrally from the abscess cavity and hemorrhagic infiltration was present for a considerable distance about the artery. The lung tissue surrounding the abscess was densely consolidated. A section for microscopic study was taken through the wall of the abscess. Histologically, the section showed a picture similar to the previous one except for a more marked and more widespread acute inflammation in the surrounding lung tissue. The walls of the bronchus lying near the abscess cavity were completely destroyed.

#### SUMMARY

Histologically, it is apparent that a true abscess is already present as early as the eighteenth or twenty-fourth hour after the lodgment of the infected embolus, and that the lesion is definitely formed after thirty-six hours. In the thirty-six hour specimen, the wall of a small bronchus is almost entirely destroyed. The extensive surrounding pneumonitis seen in the three and four day specimens simulates the lung infiltration of the early stages. The difference is one of degree only.

The entire pathologic process of embolic lung abscess can be depicted as follows: Following the lodgment of an infected embolus in a pulmonary artery, thrombosis of the vessel occurs. A cellular exudate forms in the vessel wall. The latter is gradually destroyed by bacterial action and the adjoining lung tissue becomes involved in the inflammatory

was dry, scaly, contracted, devoid of folds and roughened; in zones it was free from pigment, but in other portions it was a dirty, brownish gray. There were two firm nodules at the lower and inner margin of the organ, one measuring 1 cm. and the other 1.4 cm. in diameter. These were fixed to deeper structures and to the smooth, stretched, bluish skin that covered them. On section the surface 1 cm. distant from the nipple revealed a firm, grayish-white tumor mass fusing with the deeper layers of the skin and extending for a depth of 3 cm. to involve the gland proper and the muscles posterior to the breast. The margins of the growth were irregular, and radiating from its periphery into surrounding structures were grayish white crab-leg-like process.

The right breast was twice the size of the left, was pendulous and contained no palpable nodules.

Aside from the superficial metastases at the margin of the left breast there was an elevated, oval, firm, grayish white, immovable, subcutaneous tumor 3 by 2 cm. lying immediately above the right zygomatic arch.

Of the lymphoid tissue, the left axillary, supraclavicular and infraclavicular nodes as groups were enlarged, firm and fixed to surrounding structures. On section the surfaces were almost uniformly grayish white with only small islands of recognizable lymphoid structure present. The tracheobronchial nodes were enlarged and firm but uniformly black. Neither these nor the mesenteric or retroperitoneal groups showed tumor metastases.

**Oseous System:** The superior maxilla had an irregular grayish white tumor growth involving the nasal process, the orbital surface, the facial surface and the malar process, from the articulation of the nasal process with the frontal bone to the maxillary process of the malar bone, and from the orbital surface downward toward the canine process for 1.8 cm. In the central portion of the growth on the facial surface of the bone was the infra-orbital foramen with the infra-orbital nerve and artery surrounded by tumor growth. The growth extended to the malar bone and involved its orbital process, and to a slight extent the articular margin of its maxillary process.

The other bones of the skull contained tumor metastases with areas of consequent bone necrosis as follows:

In the frontal bone above the right frontal eminence, an oval area, 3.2 by 2.8 cm., with irregular edges, extended through the skull.

In the right parietal bone there were three oval areas. The first, 1.1 cm. in diameter, was 3.2 cm. posterior to the frontoparietal suture and 2 cm. to the right of the interparietal suture. Posterior to this almost in a direct line, 2.5 cm. and 6 cm., respectively, were the other two, measuring 1.2 cm. and 1.7 cm. each.

In the left parietal bone, posterior to the parietal prominence and extending backward to the parietal-occipital suture, was an irregular moth-eaten-like area, 5.2 by 4.4 cm. In portions of this area there was complete necrosis of both tables of bone. Around the margin small islands and projections of cancellous bone remained.

In the occipital bone, an area 3.2 by 2.3 cm. involved the entire thickness of the skull, centering about the external and internal occipital protuberances.

The right fourth rib, beginning at a point 9 cm. from its head and extending to the costal cartilage, was white like dead bone, and its medulla was filled with a firm, white tumor growth. The left second and third and the right third and fourth ribs were fractured within 2 cm. of the costochondral line at points where there were grayish white tumor growths with bone necrosis.

In the vertebral column there was a moderate kyphosis and scoliosis involving the junction of the thoracic and lumbar vertebrae. The bodies of the twelfth dorsal and the first lumbar vertebrae were almost completely destroyed, allowing a

Our belief that postoperative lung abscess results from embolism, a mechanism produced by the dislodgment of an infected thrombus from the vessels of the operative area, is based on the following facts:

1. The definitely proved existence of the condition of fatal postoperative pulmonary embolism. This supposes the possible scattering from any wound of single or multiple emboli into the venous circulation.

2. The frequent development of lung abscess after operations performed in infected or potentially infected fields. In this class we refer particularly to nose and throat operations, especially tonsillectomy, and to operations performed on the gastro-intestinal tract.

3. The high percentage of occurrence after operations performed in mobile operative areas. Thrombi are easily dislodged from such regions as the pharynx and epigastrium. In operations on the brain in which the skull acts as a splint the percentage of postoperative pulmonary complications is almost nil.

4. The not uncommon appearance after operations in which local anesthesia is employed.

5. The failure to prevent postoperative pulmonary complications with the constantly improved methods of giving inhalation anesthesia.

6. The greater frequency of lower lobe involvement. This is explained by the greater volume of blood and the more direct course of the pulmonary artery to these lobes.

7. The often symptom free period following the operation before the onset of the complication. If the aspiration mechanism were the causative factor, the appearance of the symptoms would be early.

8. The sudden pain in the chest that frequently constitutes the initial symptom and the often severe and stormy associated clinical course that follows before rupture and evacuation occur.

9. The acknowledgment by bronchoscopists that typical lung abscess is rare with the lodgment of foreign bodies even deep in the air passages.

10. The unsuccessful attempts at experimental production in animals by the introduction of infected materials by way of the air passages, either by transtracheal implantation or by aspiration.

11. The comparative ease with which lung abscess can be produced by the intravenous injection of infected materials.

A method is described for the production of lung abscess by freeing infected emboli into the venous circuit. Success depends on the type of organism employed and on the physical property of the embolus. The latter will permit the establishment of some degree of local tissue immunity so that the lesion remains localized and thereby assists toward the prevention of a rapidly spreading acute diffuse inflammation.



tilage was increased in size by an uneven elliptical callus in which there was extensive tumor tissue growth. The canal of the upper fragment of bone was filled for some distance by white, fairly firm tumor tissue. Near the middle of the shaft on the posterior surface was an irregular, moth-eaten area of bone necrosis, 1.2 by 1 cm., with tumor growth filling the space.

The right humerus, 11 cm. above the articular surface of the lower extremity, had a recent fracture with callus formation on all surfaces. The bone at this location was thin, and the canal filled with grayish white tumor tissue. The lower fragment was nodular, uneven and bent inward with a sharp angulation. There was a previous fracture 4 cm. below this where the angulation was more pronounced, and the callus, consisting in part of tumor tissue, was excessive. Beginning at the surgical neck on the external surface at the lower extremity of the bicipital groove and extending for 5.5 cm. downward, and from the inner lip of the bicipital groove backward 4.3 cm., involving the external surface, and on to the posterior surface was a tumor growth with bone necrosis involving three fifths of the bone circumference, or all but a portion 2 cm. wide.

The pelvic bones contained multiple tumor growths with corresponding areas of bone necrosis at the following sites:

At their articulation the left os pubis and left ilium had an area 4.6 by 3.6 cm., one fourth of which involved the terminal part of the upper surface of the os pubis; the remaining portion extended to the internal iliac fossa, laterally from the linea ileo pectinea to the upper rim of the acetabulum. Posterior to this 4.5 cm. a 1 cm. area involved both surfaces of the ilium. In front of the posterior superior spinous process and below the crest on the external surface, an area 1.6 by 1.7 cm. and another 4.6 by 2.3 cm. destroyed parts of the posterior superior and inferior spinous process.

The right iliac bone had along its crest 3.5 cm. posterior to the anterior superior spinous process a half moon area with the flat side 4 cm. along the crest and the circular edge 1.6 cm. on to the inner surface of the bone. Immediately above the posterior superior spinous process, separated from the crest by a 4 mm. rim of bone, involving the inner and outer surfaces, more markedly the latter, centered on the external table opposite the articulation between this bone and the sacrum was a circular area 4.5 cm. in diameter, and in front of the posterior interspinous notch was another measuring 9 mm.

On the posterior surface of the right ischium an area involved the greater portion of the inner surface and one half the external surface of the body, from the upper margin of the bone but not damaging the acetabulum, down and on to the internal lip of the tuberosity, and invading on the internal surface the first 1 cm. of the ascending ramus.

In the right os pubis on the external surface of the descending ramus at the line of fusion with the ascending ramus was an area 2.6 cm. which invaded the bone medulla but not the inner surface.

The left femur was the site of a recent amputation at the middle of the shaft. A recent incomplete fracture of the neck almost separated the head of the bone from its shaft. Approximately one half of the neck and of the shaft between the spiral line and the lesser trochanter had been eroded and replaced by firm, grayish-white tumor tissue. The involvement extended from the superior border of the neck downward 5 cm. to a point on the anterior surface of the femur corresponding to the lower border of the lesser trochanter; transversely at the widest place it measured 3.4 cm. A relatively recent transverse fracture of the shaft was present 8.5 cm. below the lower border of the lesser trochanter. The upper fragment was displaced outward and forward while the lower was outward, backward and upward. The ends of the bone, which were separated by a

# GENERALIZED OSSEOUS METASTASES SECONDARY TO ATROPHIC SCIRRHOUS CARCINOMA OF LEFT BREAST\*

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Second only to etiology, the most important phase of the practical study of tumors is the determination of the anatomic and biologic factors that facilitate or prevent metastases. The cause of cancer is as yet unsolved, but we know that the disease, regardless of its site of origin, ultimately spreads as metastatic growths throughout the body. The metastases may occur late or early, in nearby tissues or in more remote organs, and they are the important determining factor in cancer—usually bringing about the fatal result. Metastases represent cancer cells that have traveled to the point found and are growing as secondary tumors. Whether these detached tumor cells find their way by “spontaneous movements,” by “permeation” or by “forcible dissemination,” as has been stated by various writers, is of no particular importance.

There are two general routes of tumor cell dissemination, lymphatic and blood. In most instances cancer metastases occur by the lymphatic route, but there can be no doubt that cancer cells obtain access to the blood by invasion of the small veins in the vicinity of the primary tumor and even of the secondary growths. Paget<sup>1</sup> stated that cancer cell embolism is an impartial process to which all organs are liable. He further believed that in cancer of the breast “the bones suffer in a special way which cannot be explained by any theory of embolism alone.” The observation of cancer metastases in the various organs does not show an impartial distribution, or at least evidence of equal involvement of all organs on an impartial basis is not found. Some organs are almost regularly invaded, others rarely. We must assume that certain organs act as friendly ports for the entrance and selective harbors for the growth of emboli that lodge in them, while in other organs the lodged emboli are destroyed or prevented from growing. Handley<sup>2</sup> stated:

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\* From the Department of Pathology, University of Missouri School of Medicine.

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2. Handley, W. S.: Cancer of the Breast, London, John Murray, 1906, pp. 32, 36 and 37.

lesser trochanter was the seat of a fracture accidentally made in removing the body from the shipping container. At this location the bone was markedly thinned for four fifths of the circumference, and on the external surface the posterior border and a part of the internal surface had been completely destroyed for a distance of 4 cm. and replaced by grayish-white tumor growth which filled the medullary canal. On the posterior surface of the neck was an 8 mm. oval area of tumor eroding bone. On the anterior surface of the shaft, beginning 5.5 cm. above the articular surface of the condyles and extending upward 5 cm. with a width of 1.8 cm., the bone was discolored and partially resorbed, its surface roughened and eroded. On the anterior surface of the shaft immediately above the condyles were four oval areas of tumor invasion with partial bone resorption.

The right fibula had three areas of necrosis: one, globular in shape, 2 cm. in diameter, located at the head anterior to the styloid process; a second, 8 mm. in diameter, on the posterior border, 3.5 cm. above the lower extremity, and a third, 6 mm. in diameter, on the posterior surface of the external malleolus.

During cleaning, the right tibia with its corresponding fibula, was left on a table top, and the tumor growths were largely eaten out by mice, who left ragged, irregular spaces where tumor invasion had led to necrosis of the bone. The cancellous bone of both its extremities and the shaft contained twenty-one areas of tumor metastases associated with bone necrosis. These occurred most prominently as involvements of the internal tuberosity, and of the upper and lower thirds of the shaft. The largest areas were: one, 5.3 by 4.3 cm., of the internal tuberosity; a second, 6 by 2 cm., on the external surface of the shaft located 6 cm. below the articular surface of the external tuberosity, and a third, at the lower portion of the shaft, 8.5 cm. in length, involving the anterior border, the internal surface and border, and the posterior surface. The remaining shell of bone, approximately one-third the normal circumference, contained a recent transverse fracture, without separation of fragments, 6.2 cm. above the articular surface of the lower extremity. Along the external border and posterior surface of the fragments was early callus formation. On the external surface of the bone with its center crossing the line of fracture was an area of tumor growth, 2 by 1.1 cm., with bone necrosis. The other areas were distributed over all borders and surfaces of the bone and varied in size from 5 mm. to 2 cm. in diameter.

The inferior surfaces of almost the entire right internal cuneiform and the distal portion of the right scaphoid were largely resorbed, and the area was filled with a thick, putrid, purulent exudate. This bone necrosis with purulent inflammation involved an area 1.2 by 1.3 by 2.1 cm.

The articular surfaces of the long bones were nowhere involved in necrotic changes or tumor metastases. At sites of muscle and ligament attachments there were no tumor invasions of them or of bone surface from without. The periosteum was nowhere destroyed. The areas of bone resorption with their corresponding replacements by tumor metastases were in most instances surrounded by zones, a few millimeters in width, where the bone was white like dead bone, but remained as a hard, brittle rim between the area of complete bone destruction and the surrounding normal bone.

*Histologic Examination.*—Sections of the primary mammary tumor were typical of a scirrhus carcinoma. Material from the involved bone areas, growths in the bone medulla, of the right temporal tumor, and of the left axillary, supraclavicular and infraclavicular lymph nodes, revealed a scirrhus tumor identical with that of the breast.

The nearer a bone is to the site of a primary cancer, the greater is its liability to secondary involvement. In mammary cancers, the ribs and sternum are most frequently involved. The cranial bones, spine, femur and humerus are, in the order given, the next most common seats for metastatic growths. It is generally stated that the clavicle is rarely involved in breast cancers, thus being an exception to the general rule of proximity.

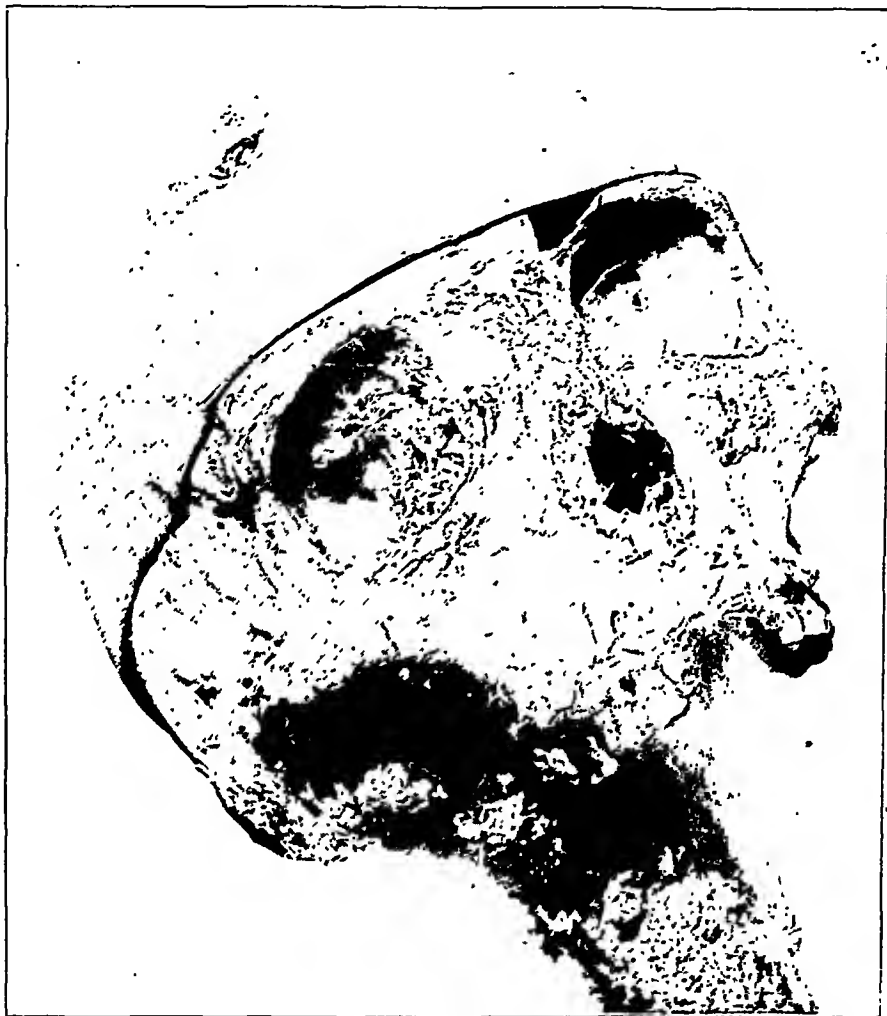


Fig. 1.—Metastatic growth of left superior maxilla involving rim of orbit; metastasis with necrosis in frontal bone.

Carcinoma invades the bones distal to the knee and elbow only in the rarest instances. The absence of records of spontaneous fracture in the distal bones does not prove that their escape from cancerous invasion is real. Invasion may be there, but we fail to search for it; and the demand on these parts is not so severe as on the other bones where spontaneous fractures are seen. We do not agree with Handley,<sup>2</sup> who says that these

# LEUKEMIA—A SARCOMA: BONE EVIDENCE

REPORT OF TWO CASES \*

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The etiology of leukemia is still uncertain. To me it resembles sarcoma in a fluid medium. It acts like a malignant growth clinically. In the two cases I report, the morbid anatomy and histologic pathology indicate it to be of a sarcomatous nature. Not only do the leukemic cells invade soft parts, but the bone likewise gives evidence of destructive action of cells and fluids. Since the original suggestion of Bizzozero, many have thought it might be sarcomatous.

Osler<sup>1</sup> in his *Principles and Practice of Medicine* writes of Willcock's case, "where there were growths on the stomach and gastro-splenic omentum, leukemic infiltration of the liver, the cells being outside the capillaries." He furthermore states, "Leukemic tumors may occur in the kidneys and liver." "Bizzozero showed these tumor cells to be in active fission." "Occasionally the sternum, ribs and flat bones show great irregularity and deformity owing to the definite tumor-like expansions."

Scott<sup>2</sup> writes:

The leukemias may be looked upon as nothing more or less than a fluid tumor, in which the constituent cells of the tumor are being carried throughout the system in the blood stream. Seldom is a true focus found. The more embryonic the cell, the more malignant the leukemia.

Simonds<sup>3</sup> writing about the Slye stock of mice says:

Leukemia, pseudoleukemia and lymphosarcoma in these mice have distinctive features indicating that they are probably fundamentally of the same nature and probably belong among the true neoplasms.

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\* From the Pathological Laboratory of the University of Maryland School of Medicine.

1. Osler, William: *Leukemia, The Principles and Practice of Medicine*, New York, D. Appleton & Co., 1892, p. 696.

2. Scott, R. E.: *Uniform Nomenclature for Blood Counts*, Mil. Surgeon 53:321 (Oct.) 1923.

3. Simonds, J. P.: *Leukemia, Pseudoleukemia and Allied Conditions in the Slye Stock of Mice*, J. Cancer Research 9:287-424 (Sept.) 1925; abstr. J. A. M. A. 86:70 (Jan. 2) 1926.

## REPORT OF CASE

*History.*—Mrs. L. W., white, aged 56, a widow, entered St. Mary's Hospital, Jefferson City, Mo., July 27, 1925, for fracture of the left thigh. No family history was obtained and the personal history, until the present illness, was unimportant. She had had the usual childhood diseases. The menses had been normal

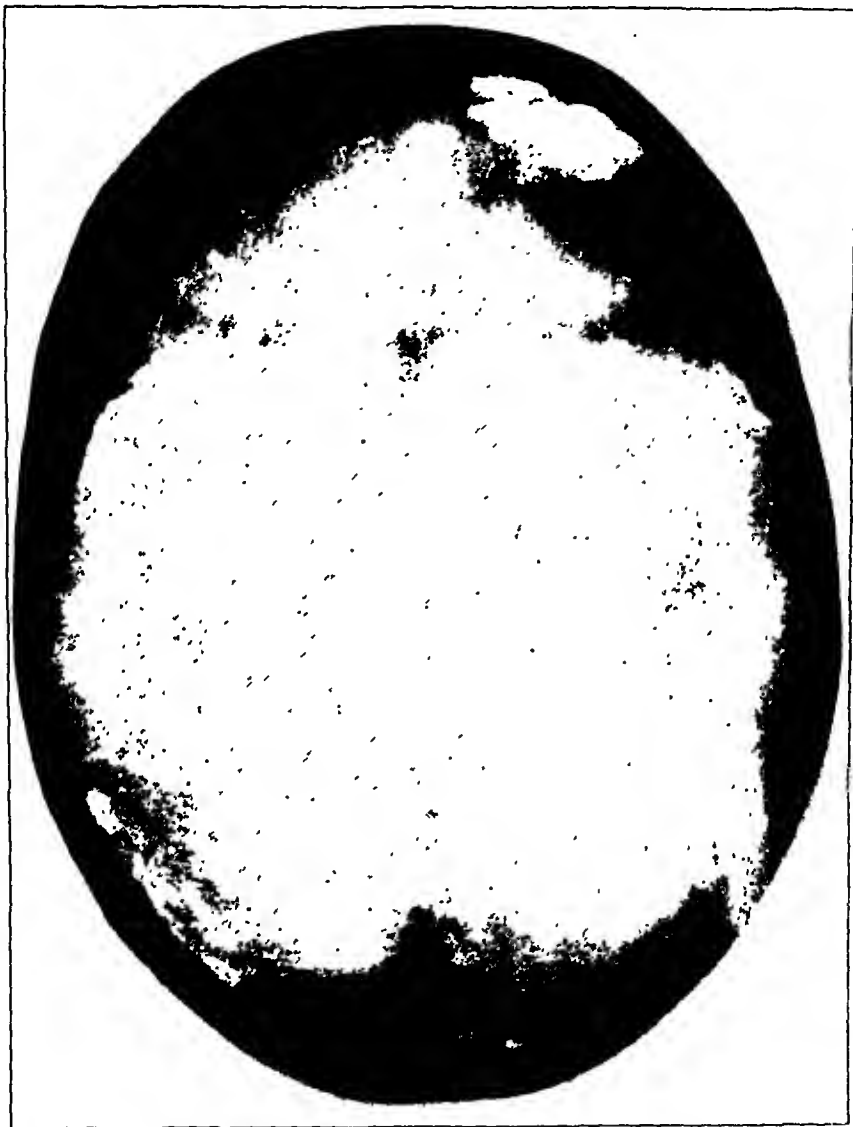


Fig. 3.—Calvarium: circular area in midline of frontal bone made for injection of brain.

with cessation at the age of 41. She married at the age of 15 and gave birth to her only child six years later. There was no history of miscarriages, operations or venereal diseases, by name or symptom.

There was spontaneous fracture of the right humerus, June 22, 1925, as the patient jumped out of bed when awakened by a rat between her legs. She landed on her feet but did not strike her arm. This arm, carried in splints, gave little

Minot and Buckman,<sup>11</sup> writing of Osler-Vasquez disease (polycythemia), refer to the coincident increase in the manufacture of myelocytes and red blood cells and suggest that we are dealing with a fluid tumor.

It has been seen associated with various infections—actinomycosis,<sup>12</sup> tuberculosis (Ellerman and Bang), fowl typhoid,<sup>13</sup> influenza,<sup>14</sup> Vincent's angina,<sup>15</sup> trauma.<sup>16</sup> The roentgen ray has produced as well as cured leukemia.<sup>17</sup> Flexner<sup>18</sup> describing lymphosarcoma holds it to be infectious in origin, although no germs were found.

Moore,<sup>19</sup> Schmeisser,<sup>20</sup> Winternitz<sup>13</sup> and Ellerman and Bang, experimenting with fowl leukemia, have not been able to prove its infectious origin.

There has always been some difficulty in distinguishing certain inflammatory growths from true tumors, especially those of a chronic nature, in which the toxins are less strong and longer acting. Here, the terms tuberculoma, syphiloma and granuloma are used. Leukemia, pseudoleukemia, lymphosarcoma, chloroma and mycosis fungoides have always been placed in a class together. More recent reports about such classification will be seen in studies of Keim,<sup>7</sup> Fraser,<sup>10</sup> Simonds,<sup>3</sup> Weber,<sup>6</sup> Fox and Farley<sup>21</sup> and Pagniez, Coste and Ravina.<sup>17</sup> These investigators consider them as closely allied tumors.

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12. Latimer, T. S.: Intestinal and Hepatic Actinomycosis Associated with Leukemia, *Tr. A. Am. Phys.* **11**:322, 1896. Welch, W. H.: *Papers and Addresses* **1**:541, 1920.

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19. Moore, V.: Infectious Leukemia in Fowls, *Ann. Rep. Bureau Animal Industries* **12**:182; **13**:205, 1895-1896.

20. Schmeisser, H. C.: Leukemia of the Fowl—Spontaneous and Experimental, *Rep. Johns Hopkins Hosp.* **22**:551, 1915.

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pelves, which were dilated and filled with grayish-yellow pus. The mucosa of the urinary bladder was covered by a necrotic, gumatous, foul smelling, grayish to black exudate. The lining, containing multiple petechial hemorrhages, was gray to black.

The ovaries, small and firm, contained multiple white scars. The uterus was small and firm, the canal partially obliterated and the cervix closed by a plug of mucus.

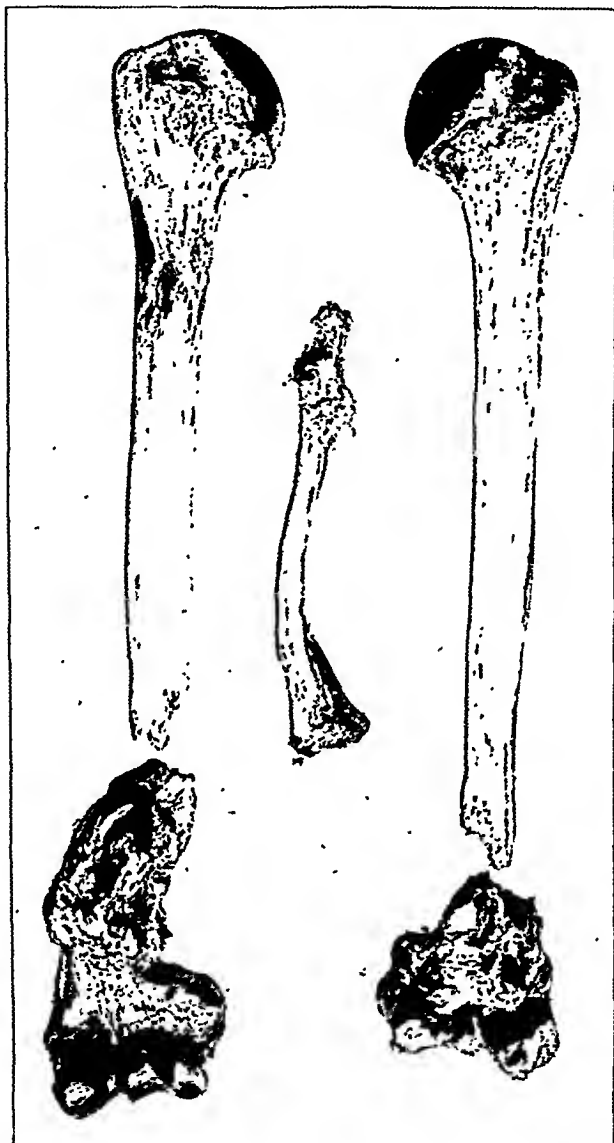


Fig. 4.—Areas of tumor invasion with resorption of bone in humeri and left clavicle, with fractures of humeri.

The meninges had adhesions to the inner table of the skull along the superior longitudinal sinus. The brain was diffuent.

The left breast had an atrophic, retracted nipple lacking in pigment, overlying an elliptical, dense, firm tumor involving the organ for an area 5.8 by 8.2 cm. The atrophic breast, with its contained tumor, was firmly adherent to the skin covering it, to the deeper tissues and to the chest wall. The skin over the breast



Margaret Lewis<sup>27</sup> grew blood cells in culture and macrophages, epithelioid and giant cells resulted.

There is a great deal of evidence from pathologic material that the marrow cells form adult connective tissue and also connective tissue that remains for some reason in its embryonal state and grows excessively (sarcoma). Bunting,<sup>28</sup> Muir and Grawitz<sup>29</sup> refer to such embryonal connective tissue growths in bone in cases of pernicious anemia. Von Recklinghausen and Paget in describing cases of osteitis deformans write of sarcoma developed in the bone marrow of some of their cases.

I see in ribs the cellular proliferation of the marrow resembling leukemia from long standing heart and blood vessel diseases with accompanying chronic passive congestion. In some the cells have developed further and formed fibrous tissue.

#### HOW EXPLAIN SARCOMA FROM MARROW, BONE, RETICULAR, ENDOTHELIAL OR OTHER MESENCHYMAL CELLS

Cells under pathologic conditions do not act just as they normally do. The nearest approach to the embryonal act of multiplying and forming tissue has been seen in cultures produced in the laboratory.

Under the stimulus of toxic materials in disease, there is seldom a perfect balance of stimulation, depression or pabulum to the cell. We see either too much or too little—not perfect physiologic satisfaction.

One can well see this in the progressive tissue changes (embryonal cell activity) in the healing of an infected wound. Cells are killed in the center of the strife against the poisons while they overgrow further away or after the bacteria or toxins have been neutralized or filtered by the surrounding tissues. We see the different effect on body cells by bacteria of the same kind but of varying degrees of virulence. The effect varies with the cell (chemical) resistance. Indeed, there are many things that tend to aid or resist the effect of toxins.

Pathologists have been striving long to discover what allows the cell, stimulated to the point of embryonal activity and appearance (in sarcoma and cancer), to remain at this stage of its life history, go no further, just continue indefinitely, multiplying as the same kind of cell or cells.

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collapse of the spine at this area with the thoracic section being bent forward at an angle of 25 degrees. Areas of tumor growth with bone necrosis were present in the anterior portion of the bodies of the third and fourth lumbar vertebrae.

The left clavicle had an area of grayish white tumor growth with bone destruction involving the acromial end, destroying in a semilunar area one third of

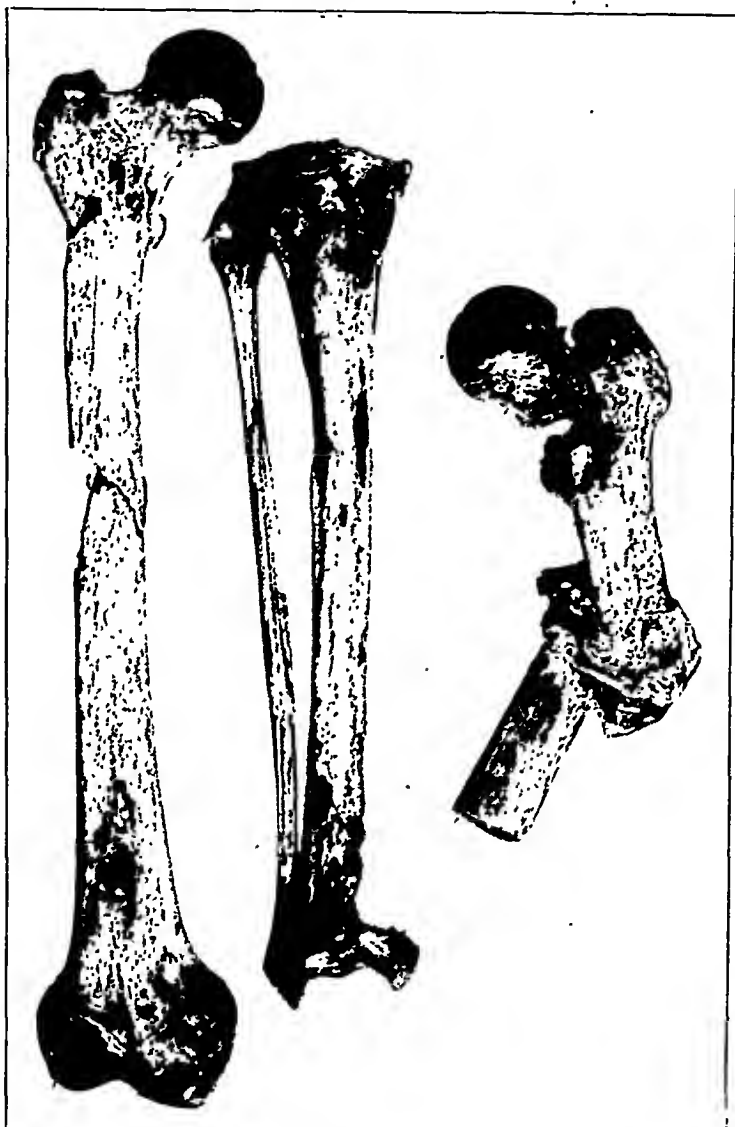


Fig. 5.—Ancient fracture of left femur with excessive callus containing tumor tissue, and erosion of surgical neck with incomplete fracture; multiple metastases in right femur, fibula and tibia, with unseparated fracture near lower end of tibia.

the articular surface and an area 1.5 cm. in diameter internal to the oblique line on the under surface, and extending to the deltoid tubercle. The right clavicle, 3.8 cm. from the acromial end, was the seat of an ancient, healed fracture with scant callus formation.

The left humerus had a recent transverse fracture 4.5 cm. above the articular surface of its lower end. The bone of the lower fragment to the articular car-

The myelocytes had escaped from the vessels in the invaded parts and had formed large masses. They caused necrosis of the tissues involved. There was evidence of hemorrhages (red blood cells and granular pigment). In the brain and bone the nuclei of some myelocytes contained karyokinetic figures.

Fresh and decalcified sections of rib and vertebra were stained as in case 2. The cortex was thinner than normal. The bone was edematous and pigmented, with blood in scattered areas of both matrix and marrow. The lamellae were swollen and there were clefts between them, some containing myelocytes; the lacunae were enlarged; the bone cells were swollen and generally well stained. Virchow's territories were numerous. There was evidence of nuclear division in the bone cells at the margins of the cancelli and wherever these cells were close

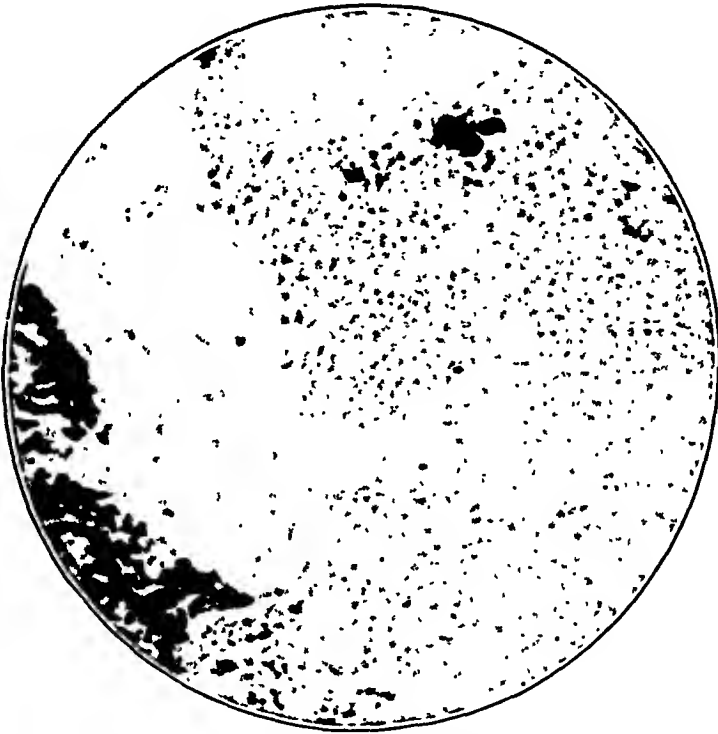


Fig. 1 (case 1).—Bone destruction by myelocytes; the bone cells are active.

to the marrow cavity and haversian canals. Many of the nuclei of the bone cells were lobulated. At times two such nuclei were seen in the same lacuna. Lacunae were frequently confluent, especially at the borders of the bone where the matrix was granular or fibrillar. Where these enlarged lacunae communicate with the marrow cavity, the bone cells were freed. Those with oval and round nuclei could be readily distinguished from the marrow cells—not so those with lobulated nuclei. There was evidence of vital and lacunar absorption of bone. Small sequestrums were seen among the marrow cells. The cancelli were grooved deeply by masses of marrow (the tumor) cells which came in direct contact with them.

The vital absorption (by fluids) was irregular in action; scattered areas appeared, the bone salts had disappeared and the matrix appeared granular.

The marrow was a mass of large cells (15 to 20 mm.) with lobulated nuclei (myelocytes) and a few with single nuclei in which nuclear division (karyokinesis) was evident.

distance of 6.5 cm., and the intervening space were encompassed by a heavy, firm callus consisting in part of tumor growth and spicules of calcified bone. The anterior surface of the upper fragment at the lower end was the seat of tumor growth and bone resorption, 2.2 cm. wide, for the distal 3 cm. Involving the linea aspera, 4.5 cm. below the lower margin of the greater trochanter, was an oval 6 mm. area of tumor growth and bone necrosis.



Fig. 6.—Spine showing collapse of twelfth dorsal and first lumbar vertebrae; tumor metastases with rarefaction of anterior portion of the bodies of the third and fourth lumbar vertebrae.

The right femur at the upper portion of the shaft involving the greater trochanter had an area of tumor growth with marked bone necrosis on the anterior and external surfaces extending from above downward for 5 cm. and involving three sevenths of the bone circumference. The cancellous bone was completely resorbed and replaced by a grayish-white tumor. The shaft 7.3 cm. below the

CASE 2.—A white man, aged 38, entered the hospital in December, 1920, and in October, 1921; he died Oct. 23, 1921. He complained of swelling of the stomach and loss of strength and weight, referring the present illness to a wrenching of his back in 1913.

There was a mass in the upper left quadrant of the abdomen extending to the right of the midline and into the pelvis. The inguinal, axillary and post-cervical glands were enlarged. The liver dullness extended 6 cm. below the costal margin. The clinical diagnosis was chronic myeloid leukemia.

The Wassermann reaction was negative. The specimens of urine contained blood and albumin. The stool showed occult blood. The red blood cells totaled 2,860,000; the white blood cells, 576,000; hemoglobin, 55 per cent; polymorphonuclear, 45.2 per cent; polymorphonuclear basophils, 0.7 per cent; polymorphonuclear eosinophils, 1 per cent; neutrophilic myelocytes, 40.6 per cent; basophilic mononuclears, 1 per cent; eosinophilic mononuclears, 1 per cent; large lymphocytes, 4 per cent; small lymphocytes, 6.7 per cent; large mononuclears, 0.7 per cent; there were 3 megaloblasts, 8 normoblasts, and a diminished hemoglobin content. Moderate anisocytosis was noted; moderate poikilocytosis; occasional polychromatophilia, and an increase in platelets; myelocytes occurred in various stages of development.

Radium treatment was used. Jan. 8, 1921, the patient was said to be improved and was discharged. The white blood cells totaled 291,700. October 12, the patient was readmitted. He had received roentgen-ray treatments to his abdomen, but the abdominal swelling increased greatly. He suffered from dyspnea, headache, vertigo and tingling in the hands.

The spleen was much larger, extending 9 cm. to the right to the umbilicus and into the pelvis.

October 15, the red blood cells totaled 2,650,000; the white blood cells, 320,000; hemoglobin, 52 per cent; myelocytes, 76.2 per cent; lymphocytes, 2.6 per cent; large mononuclears, 0.4 per cent, and polymorphonuclears, 20.8 per cent. The ophthalmoscope revealed neuroretinitis hemorrhagica. There were strabismus of the right eye, left wrist drop and aphasia.

October 20, the patient became irrational and was unconscious for two days. October 23, he died.

Necropsy revealed chronic myeloid leukemia; myeloid hyperplasia of the bone marrow, spleen and lymph glands; myeloid invasion of the lungs, brain, intestines, stomach, suprarenals, kidney and bone.

Specimens of bone from the temporal bone and the femur were examined fresh and decalcified. Hematoxylin and eosin, carbol fuchsin, gentian violet, polychrome methylene blue and picrocarmine were used. The bones were edematous and pigmented in spots by old hemorrhages. The matrix was granular, the lamellae having lost the homogeneous linear appearance in the cancelli and the cortex nearer the medullary cavity and in the bone bordering the haversian canals. Lines of cleavage due to fluid (edema) were marked between the lamellae. Plates and rods made conspicuous by vital absorption were evident. Blood pigment in granular form was seen between the lamellae in the granular matrix and lacunae. Bone salts taking hematoxylin and fuchsin stains were not homogeneously spread but occurred in islets. Some areas did not stain at all. The borders of bone next the canals and marrow cavity were often seen in a fibrillar condition.

## SUMMARY

The bone involvements described here were more massive and widespread than any found in the available literature, and showed rarely recorded invasions of some bones, such as the malar, superior maxilla, clavicle, tibia, fibula and those of the foot.

The absence of anatomic evidence of lymphatics in the bone marrow eliminates the question of lymphatic spread to this tissue.

Osseous involvements were primarily of the bone medulla with extension to the cancellous bone and bone surfaces, making it conclusive that we here had blood borne metastases.

At all fracture sites there were attempts at callus formation (extensive at older fractures) showing slight or no periosteal involvement.

There was a frank absence of permeation of the fascial lymphatics near the invaded bones, of the liver, spleen, lungs, kidneys, suprarenals, gastro-intestinal tract, genital organs and the opposite breast.

Handley's theory of permeation for bone invasion in cancer of the breast is to be rejected in this case, for if such were absolute this patient should have been literally permeated from head to foot. We do not agree with his statement that the bones distal to the knee and elbow escape simply because the patient invariably dies before growth has spread along the deep fascia far enough to reach them.

Blood tumor emboli do exist. The more one studies the occurrence of bone involvement in cancer of the breast, the stronger becomes the conviction that the invasion of distant bones must be by blood stream. Blood metastases, which are more frequently seen in cancer of the breast than in cancer of other organs, play a more important rôle than has yet been assigned to them.

This case of an unrecognized, untreated, atrophic scirrhous carcinoma of the breast reemphasizes the important rôle of metastases and of proper complete examination of patients. The tumor was in existence sufficiently long for the occurrence of widespread secondary growths, multiple spontaneous fractures with callus formation abundant in tumor tissue, and deformities incident to bone resorption without the disease being recognized.

It is unquestionable that if proper search were made, more osseous metastases would be found. We will remain in partial ignorance of the truth on this point until there is universal improvement in necropsy service. The importance of extending necropsy examinations to include the osseous system cannot be too forcibly emphasized.

cells were few in number. Here and there was a neutrophilic polymorphonuclear leukocyte. A few giant round cells containing two and three round, deeply stained nuclei were present. Some cells resembled Kolliker's osteoclasts. The protoplasm of the cells sometimes terminated in sharp points or staff shaped projections blunt at the end. It was coarsely or finely granular or homogeneous, staining deeply with eosin. The nuclei of the majority of the cells were round; many were oval and lobulated. Most of them were actively dividing, karyokinetic figures occurring. There were a number of capillaries congested with myelocytes incorporated in the cell mass in parts of the bone cavity; in other parts no capillaries were seen and few red blood cells were evident. It was impossible to distinguish red blood cells in the capillaries. The vessels in the haversian canals were better defined. They were crowded with myelocytes.

The temporal bone contained an unusual number of capillaries congested with myelocytes. Evidences of old hemorrhagic pigmentation were more marked here than in the femur. There was transition of good bone with smooth plates to reticulated matrix, to cellular bone, to masses of cells like those seen in sarcoma of the bone.

This case showed the invasive and destructive character of the growth as case 1 did, but the cells varied in size, shape and character of the nuclei. Many of the nuclei were round. There were few polymorphonuclear leukocytes. It was a mixed cell myelocytoma.

The splenic pulp was replaced in great part by these cells, few lymphocytes remaining. No lymphatic cells remained, nor was a lymphoid structure evident in the lymph glands. The gland was replaced by mixed myelocytes.

The cerebral substance had been broken down in areas and replaced by masses of the invading myelocytes. The pituitary gland had been almost completely destroyed. The vessels of the cerebrum, cerebellum and meninges were engorged with the mixed myelocytes (mostly mononuclear). Few red blood cells were seen. There were areas of pigmentation by old hemorrhage. There were bone destruction and metaplasia with a massing of myelocytes of polymorphous character.

In both these cases the myelocytes were seen keeping their place in blood vessels in an orderly way. But here and there—in the brain, liver, intestine, spleen, serous membranes and bone—there was a break and invasion occurred as in sarcoma elsewhere. The bone demonstrated masses of cells of a specific kind in the marrow. Vessel destruction and absence of other elements of the marrow were evident. There were no other cells (osteoblasts, endosteal or connective tissue cells) lining the bone, except in the temporal bone in which some of the spaces were lined by a vascular myxomatous tissue. Bone absorption by direct action of the tumor cells was noted, and there was reviving and proliferation of the bone cells such as one sees in other sarcomas of the bone.

The excuse for such a wide variance in the views of authors about the bone marrow cell growths is due to a lack of unanimity about the





# THE PATHOGENESIS OF BLADDER DIVERTICULA \*

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The mucosa of the urinary bladder is protected from herniation through the bladder wall when the intracystic pressure is suddenly raised by the arrangement of the three interlacing muscle layers. The outer longitudinal layer has large loosely woven bundles, as has the inner longitudinal layer; the middle circular layer has small bundles and is much more closely woven. In sectioning bladder walls, it was found that frequently there are left loose fibrous tissue pathways extending entirely through the bladder wall when the intracystic pressure is suddenly raised, bundle interruption to cause them to be oblique (fig. 1). Such pathways, I consider to be the necessary congenital etiologic factor in the formation of diverticula. The acquired factor is the intracystic pressure which varies according to the strength and irritability of the bladder wall, the strength being influenced chiefly by any degree of muscular hypertrophy secondary to an obstruction. Opinion in late years distinctly favors a combination of congenital and acquired factors in the pathogenesis of these malformations. Day and Martin,<sup>1</sup> Hinman,<sup>2</sup> Judd,<sup>3</sup> Lower,<sup>4</sup> Judd and Scholl,<sup>5</sup> Thomas<sup>6</sup> and Young<sup>7</sup> favor such a combination of factors. Watson<sup>8</sup> studied the vesical cavity in its fetal development and found factors which may be of importance in determining the formation of diverticula, namely, "invaginations bridging the vesical cavity, particularly near the lateral margins of the trigone."

The point that bears the greatest strain is near the border of the trigone. It is here also that many of the muscle bundles are larger, less numerous, and find their attachment, so lessening the elasticity of this area. There are more fibrous tissue pathways in this region. The

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\* From the Department of Surgery, Washington University School of Medicine, and Barnes Hospital.

1. Day, R. V., and Martin, H. W.: Diverticula of Urinary Bladder, *J. A. M. A.* **84**:268-272 (Jan. 24) 1925.

2. Hinman, F.: *J. Urol.* **111**:207-242 (Aug). 1919.

3. Judd, E. S.: *Tr. Am. Surg. A.*, 1918, pp. 519-554.

4. Lower, W. E.: Diverticula of Urinary Bladder, *Arch. Surg.* **3**:38-55 (July) 1921.

5. Judd, E. S., and Scholl, A. J.: *Surg. Gynec. Obst.* **28**:14-26 (Jan.) 1924.

6. Thomas, G. J.: *Surg. Gynec. Obst.* **23**:278-384 (Oct.) 1916.

7. Young, H. H.: *Johns Hopkins Hosp. Rep.* **13**:404, 1906.

8. Watson, E. M.: Developmental Basis for Certain Vesical Diverticula, *J. A. M. A.* **75**:1473-1474 (Nov. 27) 1920.

Again, we are drawn closer to the consideration of leukemia with the sarcomas when we see the close relationship of its cells to the more solid myelomas. Investigators find various kinds of marrow cells constituting their reported myelomas. Symmers<sup>22</sup> says, multiple myelomas are neoplasms from myeloblasts, even though myelocytes and erythroblasts are implicated. Wells<sup>23</sup> reports a case of myeloma washed out of bone leaving enough structure behind to resemble hemangiosarcoma or perivascular endothelioma. The myeloblasts were numerous. However, one will note in his case as in some cases of leukemia, that solid tumor nodules were found elsewhere in the body (in his case, in the pleura). This case makes one think that the myeloma differs from leukemia, not so much in its cells as in its consistency. That marrow cell tumors should differ one from another in the kind of marrow cell or mixture of marrow cells comprising the tumor mass is no stranger than the same occurrence in sarcoma of soft parts. That the consistency (closer or looser organization) of the tumor cells should vary in marrow also has its counterpart in sarcomas of connective tissues.

It might be objected that marrow cells are not of the connective tissue group, but they are.

Sabin<sup>24</sup> writes, "Blood is not so sharply separated from connective tissue in general. In the embryo the origin of blood from connective tissues is widespread.

Maximow<sup>25</sup> says, "The relationship between blood cells and connective tissue is so intimate that no distinct line can be drawn between them."

Carrel grew in vitro connective tissue cells from mononuclear leukocytes. "The large mononuclears became transformed into cells which assumed the appearance of fibroblasts and developed a tendency to tissue formation."

The cells in Foot's<sup>26</sup> bone marrow cultures closely resembled connective tissue cells, fat cells and clasmatoocytes.

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22. Symmers, Douglas: The Multiple Myelomata and Their Ability to Metastasize, *Ann. Surg.* 67:687 (June) 1918.

23. Wells, H. G.: The Relation of Multiple Vascular Tumors of Bone to Myeloma, *Arch. Surg.* 2:435 (May) 1921.

24. Sabin, Florence R.: Origin of Cells of the Blood, *Physiol. Rev.* 2:38 (Jan.) 1922.

25. Maximow, A. A.: Relation of Blood Cells to Connective Tissue and Endothelium, *Physiol. Rev.* 4:533 (Oct.) 1924.

26. Foot, N. C.: Growth of Chicken Bone Marrow in Vitro and Its Bearing on Hematogenesis in Adult Life, *J. Exper. Med.* 17:43. 1913.

final formation of the mouth of a ballooning cellule.<sup>9</sup> In 1 the pressure was low, in 2 slightly raised, showing a dimple, and in 3 the mucosa and submucosa are herniated through a fibrous tissue pathway, showing a typical diverticulum mouth. At this last stage, 3, a cystogram was

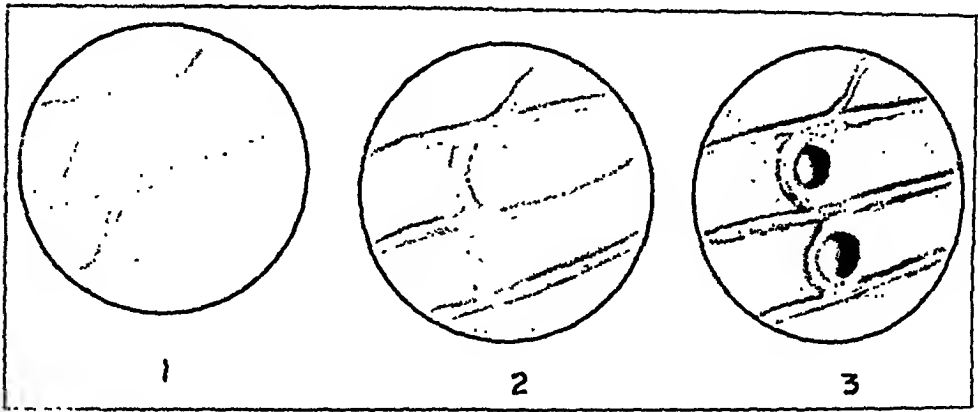


Fig. 2.—Cystoscopic views of the successive stages in the herniation of a ballooning cellule in a normal youth's bladder, brought about by gradually increasing the intracystic pressure.

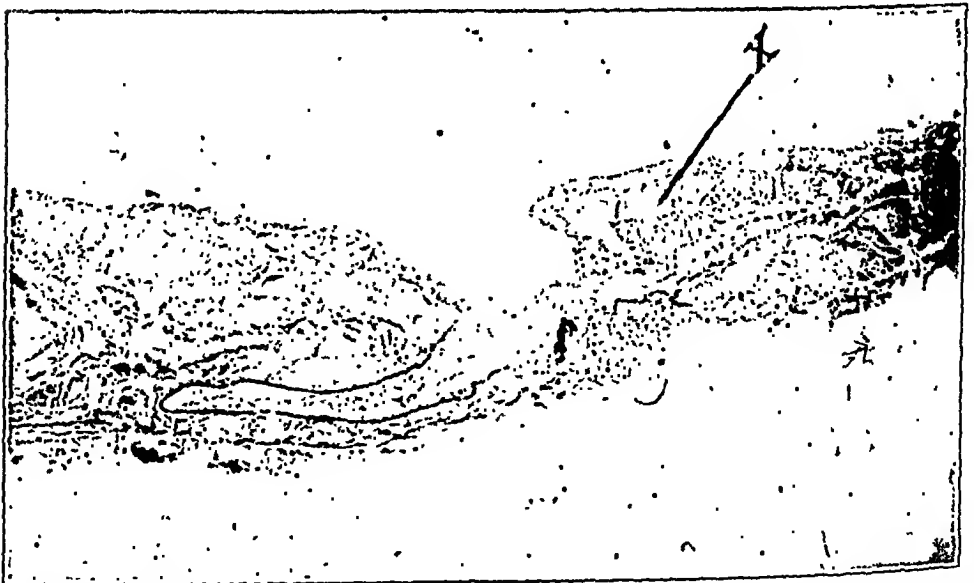


Fig. 3.—Cross section with the bladder at rest of a ballooning cellule or early diverticulum, such as seen in figure 4.

made (fig. 4) which was diagnosed early diverticulum by the radiologist. Cross section of such a ballooning cellule or early diverticulum, though somewhat more advanced, is shown in figure 3, in which the sac of the cellule, with the bladder in relaxation, lies between the middle and outer

9. Rose, D. K. South. M. J. 19:206-212 (March) 1926.

Carrel<sup>30</sup> seems to have found the answer in the fact that the malignant cell dies quickly, leaving a toxic liquid behind, but not before causing many other cells to multiply. A huge mass of embryonal cells forming sarcoma are left behind. It is easily conceivable that this process may be simulated or actually produced by infections. I have referred to the various infections associated with the leukemias. The lymphosarcomas have likewise been said to be caused by infections.<sup>18</sup> Hodgkin's disease and leukemia have both been referred to tuberculosis and syphilis.

Today there is a tendency to seek for some specific infecting agent as the cause of malignant tumors. A reversion to an embryonal type of cell is commonly seen in bone as in other tissues when influenced by toxins. In several hundred necropsies, I not only see the myelocytes multiplying in infections, wood alcohol, carbon monoxide, phosphorus and cantharides poisoning but also frequently note great increase in normoblasts and bone cell multiplication. There is usually edema with enlargement and coalescence of bone lacunae.

In the chronic cases in which the irritation has been moderate over a long period of time, connective tissue formed in the marrow while the bone matrix becomes fibrillar or fibrosed. The latter condition is best seen in Hodgkin's disease, pernicious anemia, long standing tuberculosis and syphilis.

Here, in leukemia, however, we see the embryonal cell development but as in sarcoma elsewhere the cell does not complete its full development and form the kind of tissue for which it was intended.

#### REPORT OF CASES

CASE 1.—A white man, aged 45, was admitted, April 8, 1923, complaining of cough, bloody urine and fever (102 F.). The onset had been thirteen days before.

The patient was pale, and there were numerous petechiae over the arms, legs and body. There were fresh hemorrhages in the outer quadrant of the right eye; dulness and râles at the bases of both lungs. The abdomen was moderately distended. The spleen descended 4 cm. below the costal margin and was rounded and firm. The urine contained blood and albumin. There were a few hyaline casts. Blood cultures of the heart, spleen and liver were sterile. The red blood cells totaled 2,900,000; white blood cells, 102,000; hemoglobin, 48 per cent.; myelocytes, 88 per cent; small lymphocytes, 5 per cent; N. myelocytes, 4 per cent, and polymorphonuclears, 3 per cent.

The patient died, April 10, 1923.

At necropsy the anatomic diagnosis was acute leukemia. There were numerous petechial hemorrhages over the body, and hemorrhages over the viscera, intestine, especially along the serosa of the ileum and colon, the heart, peritoneum and kidneys. There was leukemic invasion of the spleen, stomach, intestines, lymph glands, kidney, lungs, brain and bone.

30. Carrel, Alexis: Essential Characteristics of a Malignant Cell, *J. A. M. A.* 84:157 (Jan. 17) 1925.

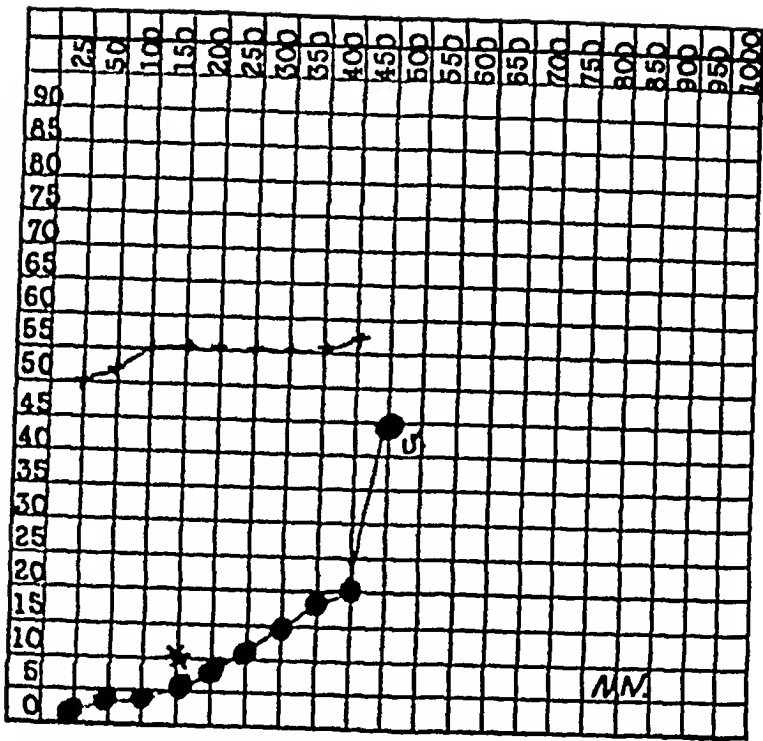


Fig. 5.—Cystometric chart of a normal bladder pressure, showing the pressure used when cystogram (fig. 7) was made.

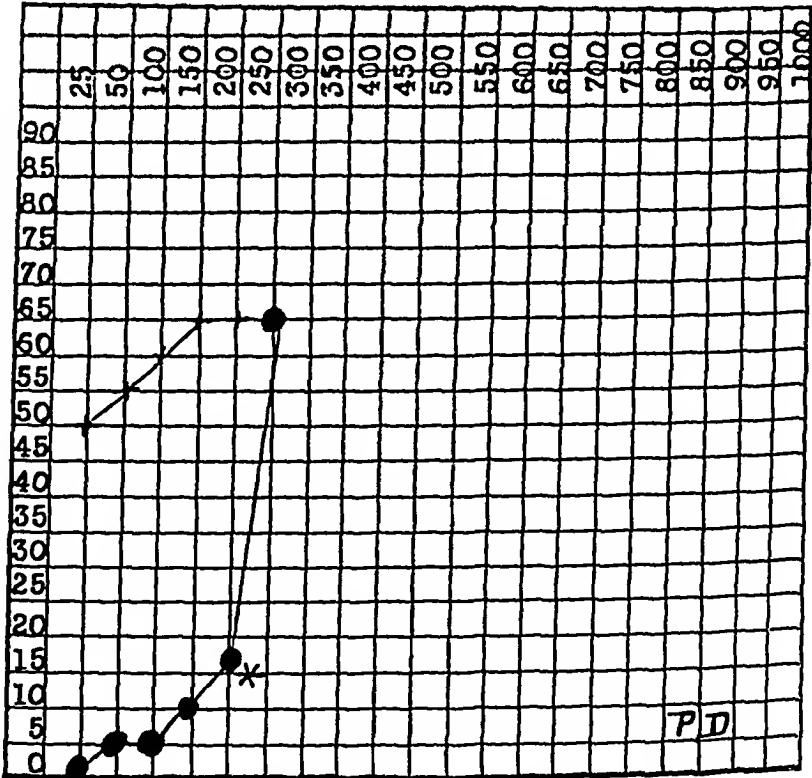


Fig. 6.—Cystometric chart in a bladder with early obstruction and hypertrophied wall, showing intracystic pressure at which cystogram (fig. 8) was made.

The cells were pressed closely together, but outlined by polygonal or irregular lines of separation. Here and there was seen a prolongation of cell protoplasm, giving the appearance of a fine reticulum between the cells. There were some normoblasts and a few larger cells (30 mm.) with from four to five deeply stained nuclei. In the dense masses of cells, few red blood cells were seen and no distinct good capillaries were evident, but one could see a few rows of myelocytes separated from the main mass by a thin swollen (edematous) capillary wall. Some remnants of degenerated vessels containing granular, pigmented, poorly stained protoplasm and fragments of nuclei gave evidence of the malignant character of the surrounding cell mass. There were areas of scattered red blood cells and blood pigment. In the haversian canals, which had not been affected by the destroying cell action, vessels loaded with myelocytes were clear cut. Where the leukemic cells border bone, there was no evidence of connective tissue, reticular tissue, vessels or "endosteal" cells. The "tumor" cells tended to arrange themselves in strata, and a fine or scarce reticulum apparently connected with the bone found its way between them. They indented the bone, forming irregular rough borders and leaving a granular unstained matrix. The lacunar cells (bone cells) stained well and showed evidence of cell and nuclear division and were in direct communication with the spaces produced by the destructive action of the leukemic cells, and in many instances appeared to become an integral part of the tumor cell mass.

A careful study of this case demonstrated small hemorrhages with pigmentation in all the serous membranes, mucosa of intestine, bladder, eye-grounds, brain, bone, heart, lung, muscle and skin. The blood vessels were engorged with myelocytes. These myelocytes were of a polymorphonuclear variety as a rule, few mononuclear or polymorphonuclear leukocytes being seen.

The blood findings showed myelocytes (polymorphonuclears), 88 per cent; small lymphocytes, 5 per cent; neutrophilic myelocytes, 4 per cent. and polymorphonuclear leukocytes, 3 per cent. The granules stained bluish black by Goodpasture's stain and blue by Schultz oxidase reaction.

The bone marrow was made up almost entirely of the large polymorphonuclear myelocytes.

In the lymph glands few lymphocytes remained. The mass was polymorphonuclear myelocytes. The spleen was made up almost completely of myelocytes like those seen in the bone marrow. There were few areas of lymphoid cells. The structure was lost.

In the liver there were masses of myelocytes replacing the degenerated liver cells in large and small areas. Karyokinetic figures were seen in some of the myelocytes. Where they remained within the vessels, there was no destruction of liver cells.

In some areas the brain substance had been replaced by myelocytes infiltrating and packing the invaded areas. Karyokinesis was evident in a few cells.

In the lungs masses of myelocytes outside the vessels invaded the alveolar spaces and their walls.

The stomach, intestines and kidneys demonstrated invasion by myeloblasts in groups outside the vessels. Some of the vessel walls were degenerated and myelocytes penetrated them. There was accompanying degeneration of the invaded tissue. Bone matrix invasion and destruction with sequestration of necrotic fragments were evident. The invading masses of myelocytes were of one type, the nucleus being lobulated.

gradual filling, the ballooning cellulæ is moderately distended and shows its pointed dependent portion, which is due to the muscle bundles of the outer layer still covering and compressing this malformation against the bladder wall. In figure 8, the bladder content is 200 cc. less; the pressure, however, is markedly raised and the ballooning cellulæ correspondingly dilated.



Fig. 8.—Cystogram of an early diverticulum with the bladder wall in spasm.

The size of a diverticulum indicates the length of time a malformation has been completely herniated through the bladder wall and subjected to a raised intracystic pressure *before infection supervened*; the size of its mouth up to a certain point follows the same rule. The orifice after having pushed back muscle bundles in its dilatation becomes so fortified that it cannot become larger, but the sacs cease enlarging only when their walls become fixed and lose their elasticity by the laying down of fibrous tissue.

In the temporal bone, large areas of matrix had become fibrillar and contained divided bone cells freed from lacunar compression (the borders of lacunae having widened and become less clear). There was much evidence of lacunar absorption by massed myelocytes pressing against the bone, grooving it like osteoclasts, and sequestered fragments of bone were seen in both the temporal bone and the femur. All the bone cells even in the denser bone, stained well. At the margins of canals and in the cancelli of the medullary cavity, they were swollen and in



Fig. 2 (case 2).—Bone erosion by myelocytes

many instances divided. The nuclei as a rule were rich in chromatin, round, oval or lobulated in shape. Three and four nuclei were seen in some of the lacunar cells. The lacunae were enlarged and many had coalesced in the softened matrix at the bone margins and at the points of massing of the myelocytes of the marrow. Here, too, the bone cell activity was more evident. The nuclei stained deeper. The marrow was packed with cells varying in size (8 to 20 mm.) and shape. They were seen in masses separated by polygonal lines of separation nearer the bone margins and appeared in pavement form. They were often seen separated as round, lanceolate, oval or polygonal cells. Normoblasts and Haidenhuin's giant



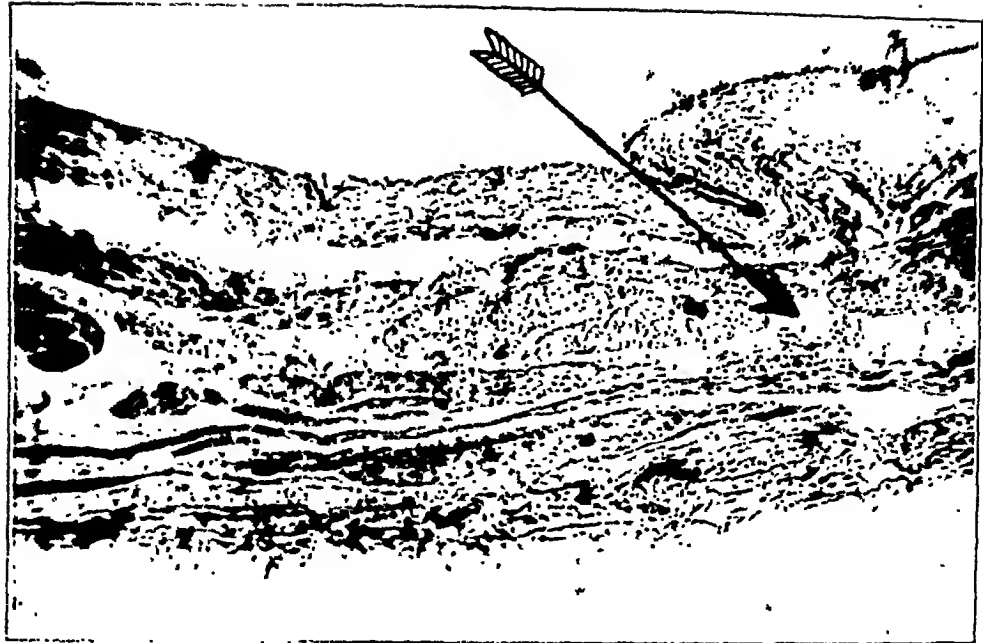


Fig. 10.—One of the first stages in the herniation through the bladder wall; the arrow points to an incomplete fibrous tissue pathway along which herniation takes place when there is a sudden rise of intracystic pressure.



Fig. 11.—Different stages of herniation in a bladder with long standing obstruction and infection.

kind of cells with which they were dealing before 1900.<sup>31</sup> This concerns especially the confusion of myeloma and leukemia.

In leukemia we are dealing with an actively growing cell. In fact some of the leukemias are definitely myeloblastic. Cells of like origin when in an embryonal state are always difficult to differentiate. Therefore, it appears that any of the mesenchymal cells of bone and marrow take part in the formation of the leukemia cells.

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31. Wallgren, Arvid: Ueber die Natur der Myelomzellen, Arch. i. path. Anat. **232**:381, 1921.

The effects of an increased intracystic pressure of long duration in a bladder with definite predisposition to herniation is shown in figure 11. There are lateral dissections under both muscle bundles and mucous membrane (in upper half); a well formed diverticulum (in middle), with its puckered orifice due to the contraction of its mouth, which shows definitely as thickened muscle bundles, and a small ballooning cellulite (near the lower margin) with a round well formed mouth but with floor still incompletely dissected through the bladder wall. This type of specimen is obtained by filling a bladder removed at necropsy with a 10 per cent solution of formaldehyde to the point, both as to intracystic pressure and fluid content, that theoretically was present when it contracted to empty itself in life.

The last stage in the herniation, or the completed diverticulum, is shown in cross section in figure 12, in which all three muscle layers are drawn to a point (*X*), the fibrous tissue sac extending on, fastening a few stray muscle bundles to itself by its inflammatory process. This idea agrees with that of Hinman,<sup>2</sup> who in his analysis of 205 cases states that the classification of Englisch<sup>11</sup> and Rathbun<sup>12</sup> of "true and false diverticula," the former showing all coats of the bladder wall and the latter only the mucous membrane, cannot be made. The thickness of the diverticulum wall is undoubtedly due to the inflammatory processes, except in true congenital malformations, such as urachal remnants and ureteral buds.

#### SUMMARY

1. Bladder diverticula are congenital to the extent that a loose fibrous tissue pathway must be present through the bladder wall before the acquired factor, namely, a raised intracystic pressure, can herniate the mucosa.

2. The occurrence of diverticula as to age and sex is determined by the size of the unprotected areas through the bladder wall, the intracystic pressure, and the variations in the fixation of the trigonal area in male and female. In females and children the normal intracystic pressure will only herniate the mucosa through a bladder wall defect of unusually wide diameter.

3. Diverticula, so diagnosed by cystogram and cystoscopic examination, in apparently normal youths' bladders, have been produced by simply increasing the intracystic pressure sufficiently to force the mucosa through an unsuspected loose fibrous tissue area in the wall.

11. Englisch, J.: *Arch. f. klin. Chir.* **73**, 1904.

12. Rathbun, N. P.: *Surg. Gynec. Obst.* **29**:28-32 (July) 1919.

combination of the two factors, lessened elasticity and more potential openings, favors the formation of diverticula, where clinically they are most often found. The female bladder differs markedly in its attachment at the trigonal border. Due to the absence of prostatic and seminal vesicle fixation, there is less loss of elasticity and consequently diverticula are less often found in the female than in the male, even with the same apparent degree of obstruction or bladder wall decompensation, as measured by the quantity of residual urine. That they do occasionally occur is due to an unusually large and lax fibrous tissue pathway which will permit a low intracystic pressure to cause the herniation.

The lessened elasticity and fixation at the trigonal border can readily be shown in a normal youth's bladder by overfilling it to the point of

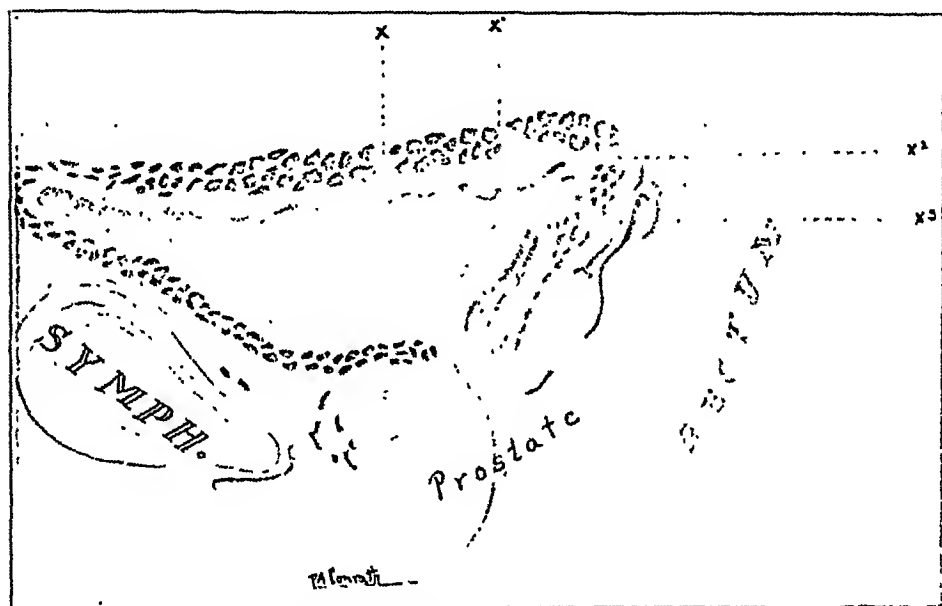


Fig. 1.— $X-X^1-X^2-X^3$ , loose fibrous tissue pathways through the bladder wall, semidiagrammatic representation.

spasm; sharp outstanding muscle bundles bounding open mouthed cellules will occur in this region, some surprisingly deep when the spasm is at its greatest. This condition lessens markedly toward the dome and lateral walls, as the muscle bundles there are more finely divided. When an obstruction occurs, the back pressure increases, which does not mean that the intracystic pressure is constantly raised, but that a greater intracystic pressure is necessary at the time of emptying the bladder. It is raised for longer periods in the early days of its residual urine or infection. The effect of a gradually raised pressure with the congenital factor present is shown cystoscopically in figure 2 by three successive stages in the herniation of the mucosa of a youth's bladder and the

# SYPHILITIC ULCERATIONS OF THE STOMACH\*

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A perusal of the American literature of the last ten years on the pathology of the stomach would indicate that gastric syphilis was a comparatively common condition. Many clinicians report a series of from twenty to thirty cases of syphilis of the stomach and certainly give the impression that not only is gastric syphilis common, but that it is also readily recognized clinically as well as at operation. A few critical reports have inadequately dispelled this idea, and up to the publication of the splendid review of Hartwell<sup>1</sup> there has been no critical analysis of the subject or of the reported data on syphilis of the stomach.

Gastric syphilis is not frequent and its clinical and histologic recognition is by no means simple or easy. Among the great number of gastric lesions seen by us within the last few years, there were three cases of peculiar ulcerations which by their gross anatomic features could be differentiated from the simple peptic ulcer on one hand and from ulcerated neoplasm on the other, without difficulty. These cases suggested to us the possibility of a specific lesion, particularly syphilis. Certain clinical features seemed to support this conception. However, a detailed histologic study compelled us to reconsider our preliminary diagnosis. We report these cases with the question in mind as to whether it is possible to determine the exact nature of such lesions from their anatomic and histologic appearance, without the demonstration of the etiologic organisms.

## REPORT OF CASES

CASE 1.—*History*.—W. E. P., a married, white man, aged 46, was admitted to the service of one of us (C. G. H.) complaining of abdominal distress and belching of gas for nine months previous to admission. Seven years before he had had trouble with his spine, his extremities being paralyzed for six months; this was diagnosed as tuberculosis of the spine. In the hospital the patient said that he now had no venereal infection but said that he had had a chancre fifteen years before and had been treated for this condition. Nine months before admission he filled up with gas immediately after taking food. Later the gas came on about one hour after meals. He had a sense of weight after eating. There was no

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\* From the Department of Laboratories and the Department of Surgery, New York Post-Graduate Medical School and Hospital.

1. Hartwell, J. A.: *Ann. Surg.* 81:767 (April) 1925.

muscle layers. In this figure, it is easy to visualize how with increased pressure the cellule would assume exactly the form that it does in the cystogram (fig. 4).

∴ Intracystic pressure has been measured by the use of the cystometer,<sup>10</sup> an instrument which records the pressure and the bladder fluid content simultaneously. Types of pressure influencing bladder herniae are shown in figures 5, 6 and 9, in which the abscissas represent cubic centimeters of fluid and the ordinates the intracystic pressure in millimeters of mercury. The asterisks mark the points at which, in the

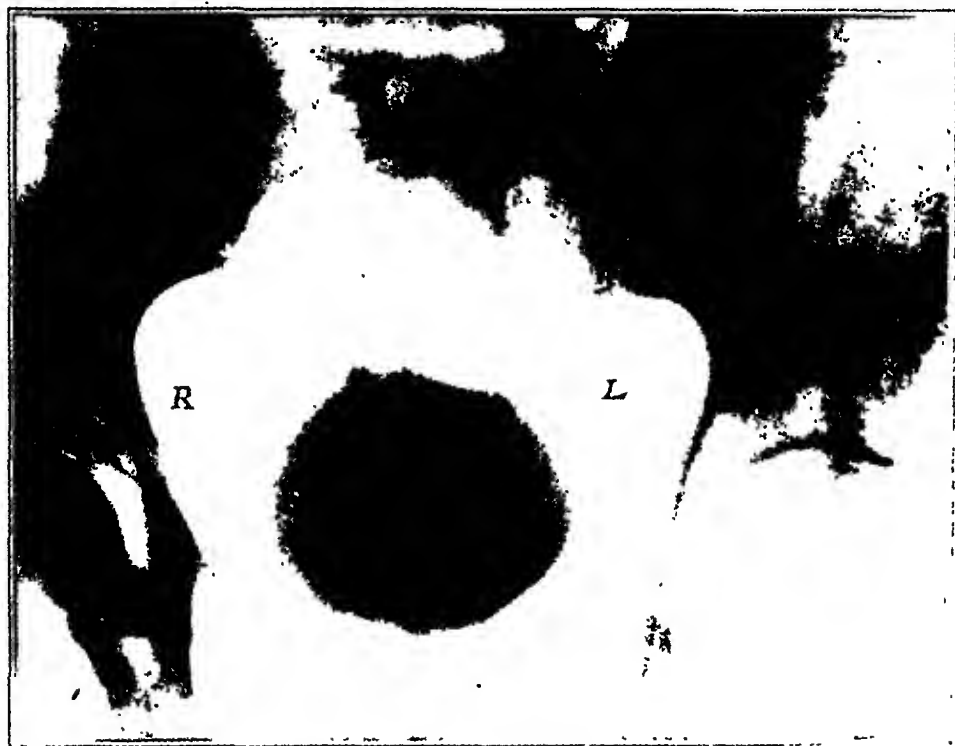


Fig. 4.—Ballooning cellule seen cystoscopically in stage 3 of figure 2: The "neck" of the malformation shows the thickness of the bladder wall.

process of gradually filling the bladder, the patient first feels a desire to void, and in figure 5 the point of involuntary emptying around the catheter or cystoscope. The lower curves (marked with dots) are formed by the contraction of the bladder wall alone; the upper curves (marked with squares) are formed by all possible forces combined, i. e., contraction of bladder wall, pressure of abdominal wall, and by the descent of the diaphragm. In figure 5 (a normal curve) the intracystic pressure rises gradually to 20 mm. of mercury when the bladder con-

10. Rose, D. K.: *Tr. Urol. Sect., A. M. A., 1920; J. A. M. A., 85:151 (June 15, 1926).*

one of the hypertrophic cirrhotic type. The patient died the third day. Permission to perform a necropsy could not be obtained.

*Pathologic Examination.*—The specimen was of the pyloric end of the stomach, 40 mm. along the lesser curvature and 100 mm. along the greater curvature. There was a portion of omentum attached to the greater curvature. The

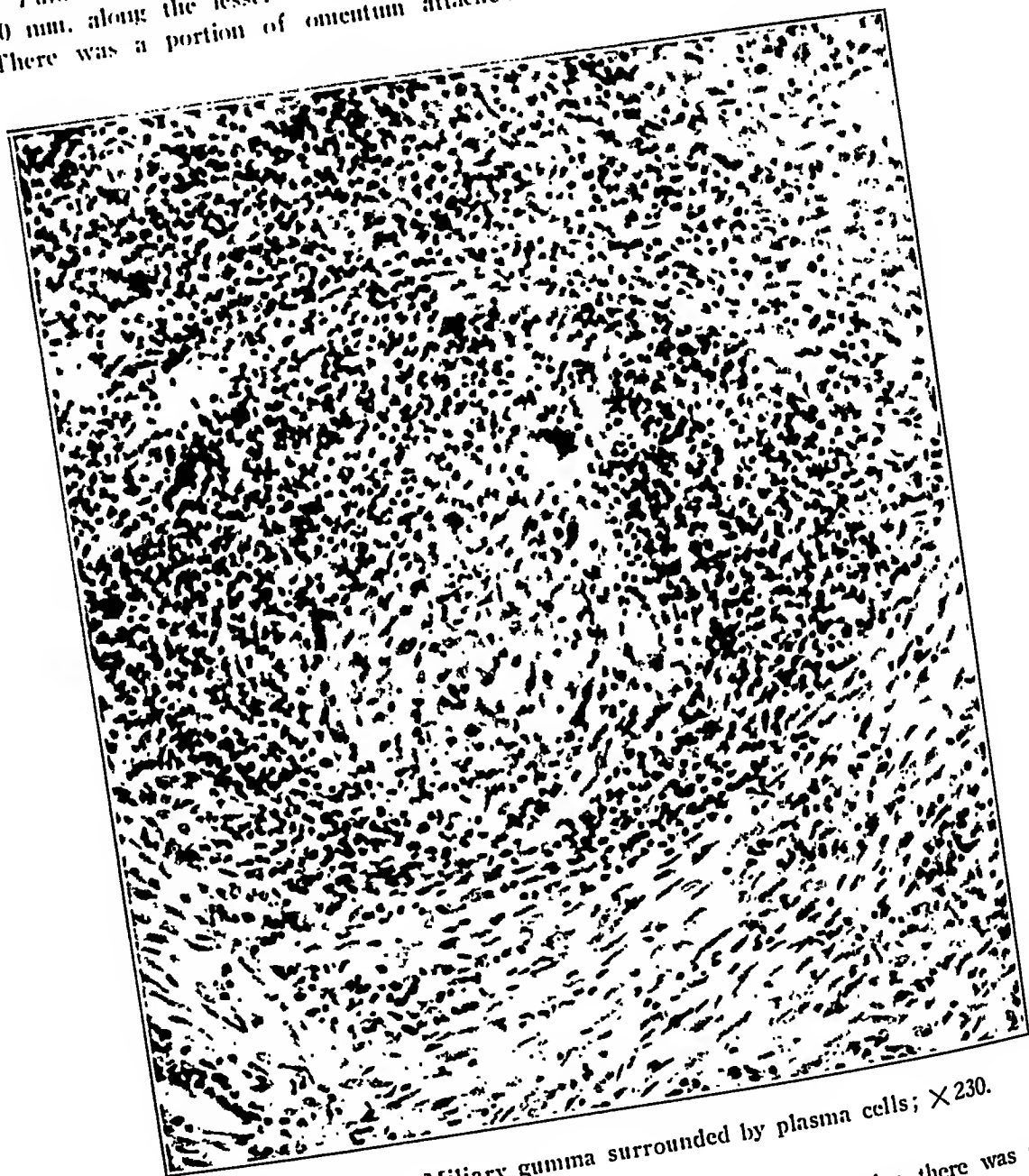


Fig. 2 (case 1).—Miliary gumma surrounded by plasma cells;  $\times 230$ .

lumen was 20 mm. in diameter at the smaller end. On section there was an irregularly outlined ulcer, approximately 30 by 13 m. in area, extending upward along the greater curvature from the pylorus. This ulcer was rather shallow; its base was fairly firm. The muscle and fibrous tissue beneath the ulcer was 13 mm. thick. In the omentum there were small firm spots, apparently lymph nodes. The largest lymph node was about 18 mm. in diameter. It appeared normal.

tracts and empties itself at 45 mm. of mercury with a content of 450 cc. of fluid. In figure 6 (representing early bladder wall hypertrophy caused by beginning prostate enlargement, with no urinary infection), as soon as the desire to void is felt, marked with an asterisk on the cystometer chart, the hypertrophied bladder wall causes spasm, raising the pressure abruptly to 65 mm. of mercury with a content of 250 cc. of solution.



Fig. 7.—Early diverticulum.

These two charts can be visualized in cystogram by making the roentgen-ray exposure the moment the intracystic pressure and bladder content (15 per cent solution of sodium bromide) are at their limits, i. e., in figure 5 the bladder empties, and in figure 6 there is intense pain due to spasm of the bladder wall. Figure 5 is represented by cystogram (fig. 7) and figure 6 by cystogram (fig. 8). In the former, by the



Within the region of the ulceration the mucosa and muscularis mucosae appeared completely destroyed. The gastric wall consisted here of a superficial layer of very cellular granulation tissue beneath a layer of edematous connective tissue, and a muscular coat on which two layers perpendicular to each other could be distinguished. The superficial layer of the submucosa appeared as a granulation



Fig. 4 (case 1).—Fibrous nodule and miliary gumma; Weigert's elastica stain;  $\times 230$ .

tissue heavily infiltrated by lymphocytes, numerous plasma cells, polymorphonuclear leukocytes, fibroblasts varying in number in different places and occasionally by large mononuclear cells with pale nuclei. The granulation tissue was rich in newly formed capillaries and small arteries. Within the layer beneath, which was composed of a loose arrangement of connective tissue fibrils, there were marked edema and an interfibrillar infiltration, with plasma cells in predominant numbers, occasional polymorphonuclear leukocytes and lymphocytes. Even within

In neurogenic bladders, the cystometric determinations demonstrate the reason for the infrequent occurrence of diverticula found, even when there is a large residual urine present due to the neurogenic obstruction. The marked difference between figures 6 and 9, the latter a neurogenic bladder wall curve in a case of *tabes dorsalis*, shows that the pressure is not due to the amount of fluid but to the strength and contractility of the wall, as we would expect. In figure 9, after the first desire to void is noted (marked by an asterisk as 600 cc.), the bladder wall can only raise the pressure 15 mm. of mercury. This type of pressure is not sufficient

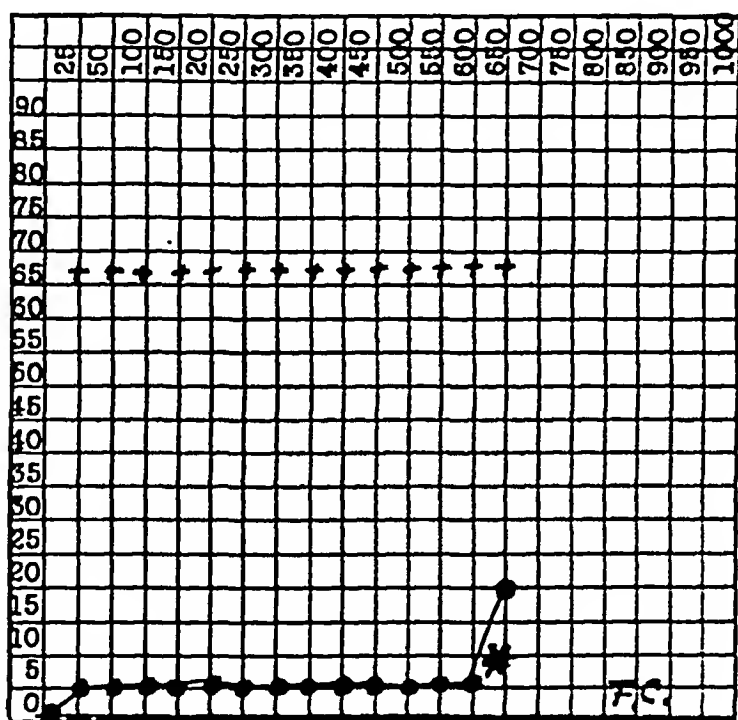


Fig. 9.—Cystometric chart showing the intracystic pressure in a neurogenic bladder (*tabes dorsalis*).

to cause the mucosa to herniate, even if a fibrous tissue pathway located near the trigon were present.

Herniation of the mucous membrane through the wall is shown in successive stages by figures 10 and 3; in the former a small peritoneal fold points toward the pathway through which a diverticulum would form if it were not interfered with by a strong outer muscle coat. The next stage (fig. 3) shows the continuation of this fold in its descent through the bladder wall. It is still withheld from breaking through by the outer muscle layer, but the sac now lies between the middle and outer muscle layers. In the absence of infection it remains closed and so by dilatation forms a ballooning cellule or small diverticulum whose

*Röntgen-Ray Examination* (Dr. W. H. Meyer).—A rather wide gap of poor, irregular filling was seen in the immediate prepyloric region. This defect measured about 1 inch (2.5 cm.) in length; the canalization was narrow and irregular. The bulbous of the first portion of the duodenum was large and irregular. Peristalsis was sluggish, these peristaltic waves disappearing in the antrum at the point of



Fig. 5 (case 2).—Epithelioid cell tubercle originating within a lymph follicle of the mucosa in tuberculosis of stomach;  $\times 200$ .

the defective filling mentioned above. Evacuation was delayed with a medium sized gastric and duodenal residue at the end of six hours. Otherwise, motility was comparatively normal.

The pathologic conditions were those of partial pyloric obstruction. The defective filling was rather suggestive of infiltration; whether primary pyloric or secondary to retroperitoneal or pancreatic involvement was not determinable. The lesion did not have the characteristics of a primary pyloric malignancy, but simu-

ever the intracystic pressure is sufficient. Infection will later gradually fix the malformation so that its wall will become permanently and either partially or entirely without the bladder wall surface, at which time we have the true small diverticulum formation, and at which time only does it become a surgical condition. Before such fixation, removal of the obstruction alone is indicated.



Fig. 12.—Fully formed diverticulum with muscle layers drawn together at X, the remaining diverticulum sac being of fibrous tissue with an occasional small muscle bundle.

To explain the formation of diverticula in children, it is only necessary to consider that the larger the congenital defect in the bladder wall the less intracystic pressure is required and the shorter the duration necessary for this normal intracystic pressure to continue in order that a diverticulum may be formed.

restless and weak; the pneumonia grew progressively worse; the patient became more and more exhausted, and died, Jan. 8, 1925. No necropsy was obtained.

*Pathologic Examination.*—The specimen was a piece of the prepyloric portion of the stomach, which had been opened. It measured 140 by 120 mm. in diameter. There was adherent omentum, in which numerous glands the size of a pea were found. Near the pyloric end was an ulceration of irregular outline, which con-



Fig. 7 (case 2).—Focal phlebitis;  $\times 180$ .

sisted of two parts connected by a narrow furrow, one part measuring 50 by 20 mm. and the other 30 by 20 mm. The margin was in part smooth, partly, however, serpiginous, and it was slightly overlapping. The base of the ulceration, which was about 4 mm. deep, was grayish with small areas of granulation tissue. The submucous coat was considerably thickened and edematous. The remainder of the mucosa was smooth and showed hemorrhagic spots. On the serosa corresponding to the areas of the ulcer there was a hemorrhagic area the size of a

4. Cystograms of diverticula should be made with known quantities of fluid and known intracystic pressure so that the elasticity of the sac can be determined, as potential diverticula (ballooning cellulæ) indicate only a removal of the bladder obstruction.

5. This theory of herniation can account for all types of bladder diverticula except ureteral buds and urachal remnants.

The submucosa, the muscularis mucosae and the serosa were infiltrated by diffuse granulation tissue and tubercles.

The base of the ulcer was formed by the submucous; the mucosa and the muscularis mucosal were absent. The submucosa was covered by a layer of necrotic tissue. The width of the submucosa was much greater than in the vicinity of the ulcer; this was because of the extensive cellular infiltration, which was partly



Fig. 9 (case 2).—Tubercle within a regional lymph node.

diffuse and partly in the form of tubercles and edema. Here conspicuous perivascular arrangement of the cellular elements was noticed, plasma cells, lymphocytes and epithelioid cells being the main constituents. Occasionally, within the perivascular infiltrate composed of plasma cells were small nodules composed entirely of epithelioid cells, with an occasional giant cell of the Langhans type.

The muscularis showed marked edema; diffuse cellular infiltration and tubercles were prevalent, with occasional Langhans' giant cells. The serous coat also showed tubercles and lymphocytic infiltration.





The mucous membrane showed almost circular ulceration, which consisted of several fused ulcers showing serpiginous, slightly elevated, red margins. The base of the ulceration was grayish and translucent. At a short distance from the circular irregular ulceration was another ulceration, very irregular in outline, which was not as deep as the other. The mucous membrane of the stomach adjacent to the ulcer appeared thickened.

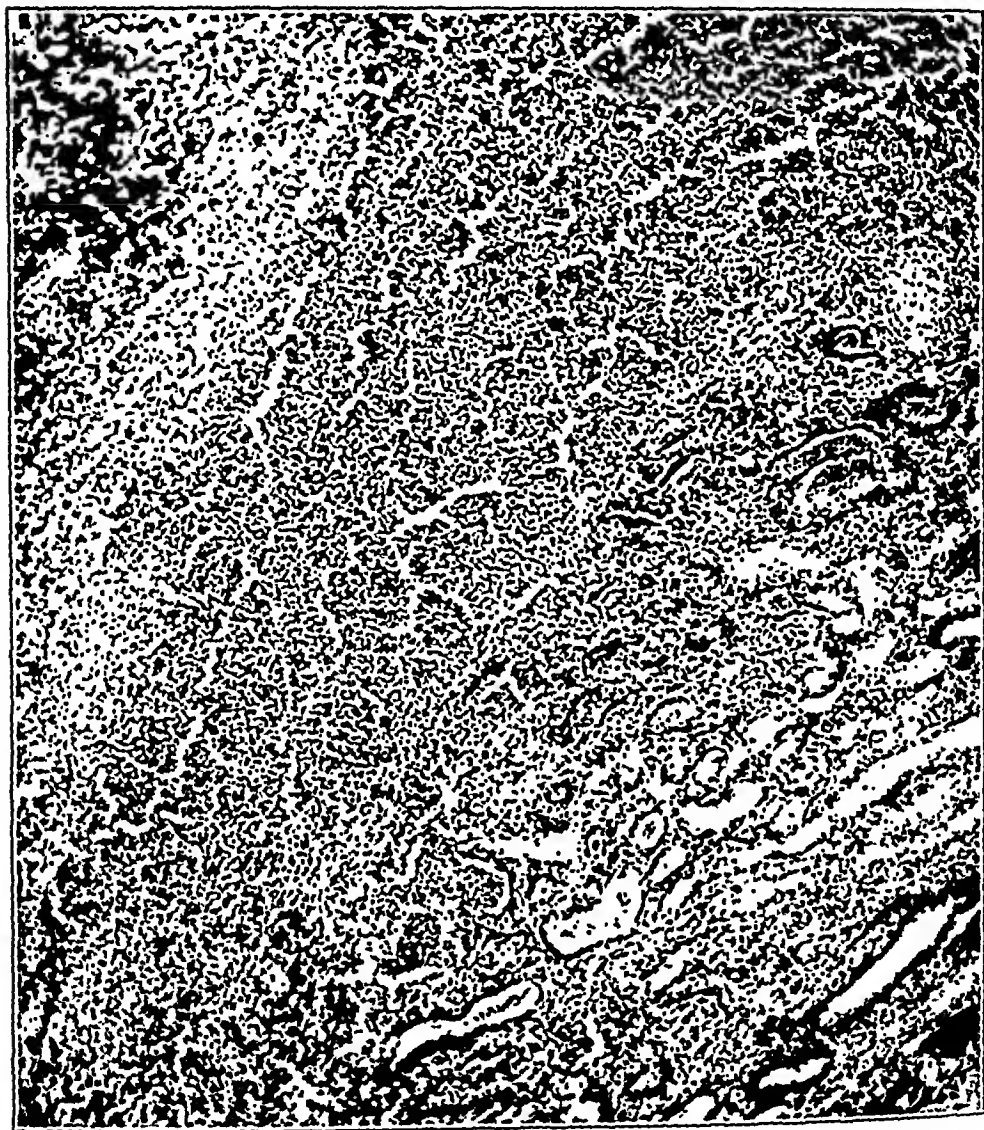


Fig. 10 (case 3).—Edge of the ulcer.

*Microscopic Examination.*—Secretions from numerous parts of the multiple ulceration revealed an almost identical picture. The mucosa and the muscularis mucosae were absent. The base of the ulcer was formed by the markedly thickened and infiltrated submucosa which was covered by necrotic tissue, invaded by numerous polymorphonuclear leukocytes and eosinophils; a fibrin network was observed in this necrotic mass. The superficial layer of the submucosa was densely infiltrated with almost exclusively polymorphonuclear leukocytes and eosinophils, with sprouting capillaries and occasional wandering

*Microscopic Examination.*—Sections from the wall of the ulcer showed the surface epithelium of the mucosa desquamated. The pyloric glands were here and there dilated and branching. The stroma of the mucosa showed extensive infiltration with polymorphonuclear leukocytes and plasma cells. At the base of the mucosa were several ill defined nodules composed of large spindle-shaped



Fig. 3 (case 1).—Fibrous nodule and miliary gumma; hematoxylin-eosin stain;  $\times 230$ .

cells with pale nuclei intermingled with lymphocytes, a few polymorphonuclear leukocytes and plasma cells. Within these nodules there was a small number of giant cells with peripherally arranged dark nuclei. The submucosa and the underlying muscularis showed edema, and the muscle fibers of the muscularis were separated by strands of polymorphonuclear leukocytes, lymphocytes and plasma cells.

does not justify the assumption that the condition in the stomach is necessarily due to the syphilitic infection, nor can the fact that patients with a clinical and roentgenologic diagnosis of ulcer of the stomach healed under antisyphilitic treatment be taken as establishing a syphilitic specificity to the ulcer. To us it is necessary to have unequivocal proof in one of three ways to establish the diagnosis of syphilis of the stomach. In the order of importance they may be summarized as follows: (1) roentgenologic diagnosis; (2) histopathologic diagnosis, and (3) the bacteriologic diagnosis—the finding of the spirochete in the tissues of the removed segment of stomach. It may be granted that the presence of a marked gastric deformity on roentgenologic examination and its entire disappearance under antisyphilitic treatment must be accepted *a priori* as evidence that the lesion was syphilitic. The deformity, however, must be of the nature of a distinctly deforming character, such as an hour-glass contracture, and not just the defect in luminal outline that goes with simple ulcer.

Many cases diagnosed as ulcer of the stomach occur in persons who have a positive Wassermann reaction, and simultaneously with antisyphilitic treatment the ulcer undergoes a spontaneous resolution and cure. Improvement in the general physical welfare of the patient is undoubtedly a factor in the cure of the ulcer, but the fact that an ulcer responds to treatment for ulcer in a syphilitic patient does not give us any positive data or entitle us to state that the ulceration is of syphilitic character. At the most it would be a nonsyphilitic gastric or duodenal ulcer in a man with a chronic syphilitic infection. In the histologic pictures of syphilitic lesions of the stomach we have the most intricate and complex problem. The histopathologic changes in tuberculosis and syphilis of the stomach are so close and simulate one another so frequently that it is only with the greatest nicety of judgment that some cases are placed in one or the other category. The final test, and to our minds, the crux of the situation, is the presence of the spirochete in the tissue itself. This must be an infrequent occurrence, for in McNee's case, the only one, we believe, reported up to date, after repeated sections he found only one field with spirochetes present. We feel, therefore, that a study of the cases along the three lines indicated, roentgenologically and histologically, with the attempt to detect the spirochete, is the line of study that should be assumed in all cases in which the question of diagnosis of syphilis of the stomach is concerned. It is interesting to note that in case 3 the surgeon (C. G. H.), with no thought in his mind of syphilis of the stomach, noted the widespread abdominal changes and the absence of the left lobe of the liver, also the scarring and general pathologic features of the liver, criteria sufficient in his mind to suggest a chronic syphilis, but without establishing the pathologic identity of the gastric tumor. Again, in

the low power magnification a perivascular arrangement of the plasma cells could be readily recognized. Because of this arrangement, the infiltration appeared to be of a nodular type. The center of such nodules occasionally showed a proliferation of large spindle-shaped cells with pale nuclei. In one of these nodules giant cells of the Langhans type were detected.

The cellular infiltration extended in a more diffuse manner into the muscular coat, but even here the nodular arrangement was not entirely missing and generally showed the same perivascular grouping around small blood vessels. Within the nodules of the muscular coat, however, lymphocytes were predominant, whereas the diffuse infiltration was made up chiefly of plasma cells.

The conspicuous perivascular type of the cellular infiltration necessitated a further detailed study of the medium sized and small blood vessels. The cells composing the granulation tissue were not restricted to the perivascular areas. They invaded the blood vessel walls, starting from the adventitia and advancing to the lumen with simultaneous destruction of elastic coats. In such blood vessels the intima was markedly thickened and the lumen narrowed. Numerous veins were completely obliterated, their lumina filled by granulation tissue, with Langhans' giant cells. In the sections stained with hematoxylin-eosin such vessels resembled tubercles. Their true nature was revealed by application of Weigert's elastic stain.

Sections from lymph nodes showed enlarged lymph follicles with large germinal centers.

Impregnation with Levaditi's silver method did not reveal spirochetes. A stain for tubercle bacilli remained negative.

The diagnosis was syphilis of the stomach.

**CASE 2.—History.**—D. G., an unmarried colored man, aged 25, was admitted to the medical wards, Dec. 16, 1924, complaining of abdominal distention and discomfort after meals for nine months previous to admission. He had vomited after meals for one month. In the past there had been slight occasional tachycardia and palpitation. Gonorrhea eleven months previous to admission was followed by buboes. He said that he had not had syphilis. He had suffered from gas in the gastro-intestinal tract and heartburn for the last nine months, and he was constipated. His appetite was good. Nine months before admission, the patient began to suffer considerable abdominal distress, gas, heartburn, distention and belching of gas about fifteen minutes after eating. At first these symptoms following meals occurred only occasionally, but they had recently become progressively more frequent and intense. The belching of gas relieved this distress; his appetite was good, but he limited his diet because of fear of distress. One month before admission he began vomiting at the height of distress. The vomitus consisted of recently ingested food and at first relieved the distress. Two weeks before admission to the hospital it appeared rather black, but no bright red blood could be noticed. The bowels were constipated. Two weeks before admission, he had tarry black stools, lasting for several days. He had lost 20 pounds (9 Kg.) in weight during the last nine months with a simultaneous loss of strength.

**Laboratory Examinations.**—The red blood cells totaled 4,162,000; the white blood cells, 5,050; the hemoglobin content (Sahli), 73 per cent; polymorphonuclear leukocytes, 62 per cent. There was a moderate trace of albumin in the urine; the sediment showed numerous pus cells. An Ewald meal showed free hydrochloric acid 23.6, combined 15.6, total 48.6. Blood in the gastric contents was strongly positive. The blood chemistry was normal. Four Wassermann reactions, one provocative, were negative. Tested for blood, the feces were strongly positive.

with the criteria for differential diagnosis between syphilis and tuberculosis in other organs, we strongly considered the diagnosis of syphilis in case 1 and of tuberculosis in case 2. We felt, however, that these differences cannot be accepted as full evidence on which an etiologic diagnosis can be based. In the absence of demonstrable etiologic factors (i. e., tubercle bacilli or spirochetes) we had to look for additional clinical or anatomic proofs to strengthen the morphologic evidence.

In case 1, we felt assured of our diagnosis of syphilis because of the history of chancre fifteen years previous to operation and the operative observation of a hepatic scar which impressed the unbiased surgeon as syphilitic. In case 2, however, the diagnosis of tuberculosis was sustained by the absence of any clinical evidence of syphilis, namely, the negative history and the repeated negative Wassermann reactions.

In the third case, a diagnosis of syphilis could not be made although the gross appearance was highly suspicious and the operative observation of liver changes, such as hepatic scars and the absence of the left liver lobe, were suggestive of tertiary syphilis. The lack of histologic evidence of a syphilitic granulation tissue as found in the first two cases ruled out syphilis or tuberculosis. We feel, however, that this case deserves special comment because of its peculiar macroscopic and microscopic character. The most conspicuous feature was the appearance in the gross, but microscopically also it differed from a simple peptic ulcer. The outstanding histologic features were the extensive infiltration with polymorphonuclear leukocytes; these leukocytes frequently formed small abscesses within a granulation tissue of nonsyphilitic nature. These features are those of a chronic recurrent suppurative inflammation and suggested a search for fungi as the possible etiologic agent, but this was made with negative results. We were unable to determine the nature of the unfamiliar picture since no bacteria were found and the histologic character was nonsyphilitic.

The study of these three unusual cases has led us to conclusions which primarily were applied only in our own cases. We feel, however, that these considerations might hold in other similar cases in which the gross appearance is suggestive of a syphilitic gastric lesion. It is evident that the macroscopic picture must not prejudice one in favor of a diagnosis of syphilis. In the microscopic diagnosis the greater difficulty is in the differentiation between syphilis and tuberculosis. The points of difference are not so definite that they can be accepted as absolute proof of either one or the other condition. If corroborated by clinical and anatomic evidence, however, they do permit a diagnosis one way or the other.

lated the condition usually observed in syphilis. Comparative examination after administration of atropine confirmed the opinion that there was benign infiltration.

In spite of four negative Wassermann reactions and a negative history, the diagnosis of syphilis of the stomach was made.

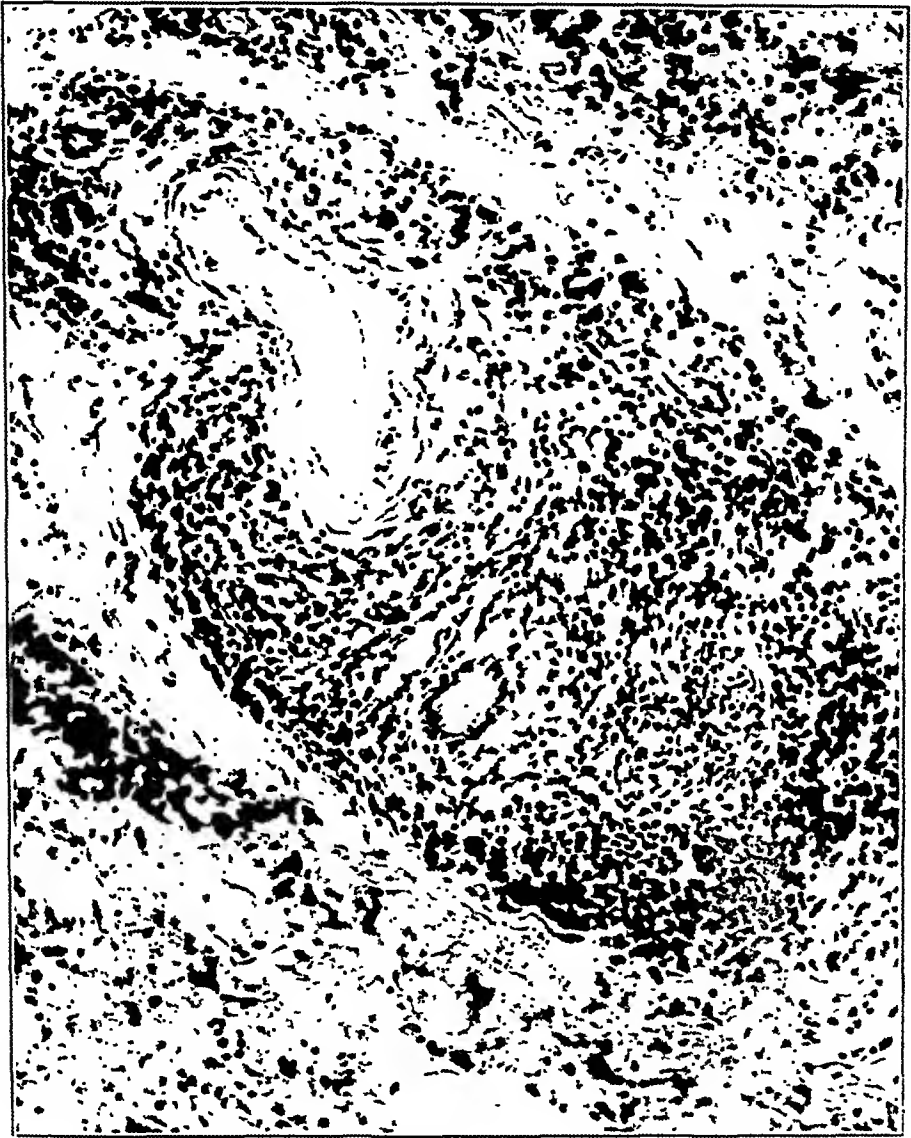


Fig. 6 (case 2).—Miliary tubercle within a perivascular plasma cell infiltrate;  $\times 230$ .

*Course.*—The patient's condition became gradually worse; he vomited often, and the symptoms of pyloric obstruction made it necessary to perform an exploratory operation. This was done by Dr. John F. Erdmann, Jan. 2, 1925. An ulcerated, infiltrated pyloric end of the stomach was removed with subsequent Polya anastomosis. The postoperative diagnosis was gastric ulcer with infiltration and stenosis.

On January 5, examination of the chest revealed a double bronchopneumonia. The temperature was 103.6; pulse, 160, and respiration, 60. The patient was

# DISLOCATION OF THE SEMILUNAR BONE

## NEUROSPASTIC FIXATION OF THE HAND: A DEFORMITY CHARACTERISTIC OF THE INJURY\*

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Dislocation of the semilunar bone, designated by some as backward displacement of the os magnum, by others as perilunar dislocation of the carpus,<sup>1</sup> and by still others as subtotal retrolunar subluxation,<sup>2</sup> is the third most frequent injury to the wrist bones. It is much more rare than Colles' fracture or fracture of the scaphoid, but its importance is second to neither if the possibility of serious permanent disability is to be considered. Grave results occur from failure to diagnose the condition and from neglect to apply proper early treatment.

At present, information in textbooks is meager and indefinite. Many contributions to the literature fail to emphasize fully the serious possibilities of permanent disability, and surgeons do not consider it as an injury of major importance.

Since the advent of workman's compensation insurance laws, and the consequent more frequent exposure of unfavorable results, this injury can no longer be considered a surgical curiosity. It is more common than is generally thought, and failure to institute early treatment can be so disastrous to the hand that every detail of its clinical characteristics should be made as common knowledge as that of Colles' fracture and other better known fractures.

It seems, therefore, that definite conclusions should be reached in regard to the management of the injury as it must be placed in the list of injuries that may produce severe loss of function.

The following eight cases selected from my own records illustrate how serious some cases may be and how widely the clinical aspects may vary. In the first case to come under my observation, case 1, the marked disability and disappointing results of treatment aroused my interest in the subject.

CASE 1.—F. N., a white laborer, aged 36, was admitted to the hospital, Jan. 4, 1921, stating that ten weeks previous to admission he had injured his wrist while cranking an automobile. Without making a roentgen-ray examination, I made a

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\* Read before the Section on Orthopedic Surgery at the Seventy-Seventh Annual Session of the American Medical Association, Dallas, Texas, April, 1926.

1. Speed: *Traumatic Injuries of the Carpus*, Philadelphia, D. Appleton & Co., 1923.

2. Mouchet: *Presse méd.* 58:585, 1919; *Am. J. Surg.* 84: (Aug.) 1920.

silver dollar with a central flat nodule which appeared to be connective tissue. The glands were grayish and edematous.

*Microscopic Examination.*—Sections from the wall of the ulcer showed desquamation of the surface epithelium. In parts the pyloric glands were disintegrating. The interglandular areas were infiltrated with a granulation tissue composed of numerous plasma cells; many epithelioid cells; polymorphonuclear



Fig. 8 (case 2).—Focal destruction of the lamina elastica with endarteritis;  $\times 30$ .

leukocytes; small round cells; eosinophils; a number of cells aggregated in nodular form, composed of lymphocytes, and epithelioid cells, with occasional giant cells in the somewhat rarefied center. Close to the ulcer the mucosa suddenly ceased and in some areas the descent was steep. Other sections, however, showed an undermined overlapping mucosal border, the defect being caused by the absence of muscularis mucosae, which in its intact portions from the wall of the ulcer appeared edematous and infiltrated by similar granulation tissue.



diagnosis of Colles' fracture. The patient said that there had been little immediate deformity, some swelling and considerable pain. An attempt was made at reduction by pulling on the hand, without giving the patient an anesthetic. A ready made anterior aluminum splint was applied, leaving free motion to the fingers, and 15 degrees of flexion to the wrist. The following day, severe pain continued, and the hypodermic injection of an analgesic was required. The roentgen-ray report was that there was no evidence of fracture. Pain of a burning, throbbing nature persisted. After three weeks, another roentgenogram was made, and the report was "forward dislocation of the semilunar bone." No attempt was made at reduction. The patient was advised that open operation would be necessary, but this was



Fig. 3.—*A*, appearance after operation: The semilunar bone is missing and the head of the os magnum appears to be articulating on the radius. *B*, calcareous atrophy; the scaphoid appears short because of the rotation and the slight flexion of the hand. The space left by the semilunar bone should be noted.

delayed. On admission, ten weeks after injury, the right hand was rigidly fixed in a striking attitude (fig. 1). The wrist was flexed at 15 degrees, with no motion. There was a small amount of voluntary movement in the fingers. A slight prominence was noted at the base of the palm; the knuckles were prominent, the skin was adherent; the fingers were held slightly flexed. Roentgen-ray examination showed dislocation of the semilunar bone forward in a perpendicular position, with the concave surface facing the palmar aspect (fig. 2). There was considerable roughening of the carpal articular surfaces and evidence

The blood vessels throughout showed severe changes. All coats of the numerous arteries as well as the venous channels were pervaded by granulation tissue and some of the blood vessels showed destruction of their coats. In such vessels the intima showed thickening, the lumen was irregularly narrowed and the continuity of the elastic coats was interrupted. However, no complete obliteration of the blood vessel lumen was noticed in any of the numerous sections.

Concerning the lymph nodes, the periglandular fat and connective tissue showed several tubercles and also diffuse lymphocytic infiltration. The lymph glands proper showed large lymph follicles with large germinal centers and several tubercles with Langhans' giant cells and caseation.

Guinea-pigs were inoculated and direct cultures and smears made. The antiformin method was applied to numerous frozen sections. Levaditi impregnations for spirochetes were done. All were negative.

The diagnosis was ulcerative tuberculosis of the stomach.

**CASE 3.—History.**—P. W., a white woman, aged 37, who had been married ten years, was admitted, Feb. 27, 1925, to the service of one of us (C. G. H.), complaining of pain in the right upper quadrant of one year's duration. She had no children and had had no pregnancies. For the last year the patient had had frequent attacks of pain in the right upper quadrant, the last attack occurring on the day previous to admission. The pain was sharp at times, dull at others, radiating to the back but not to the shoulders; it was accompanied by vomiting and relieved after vomiting. The patient vomited three times on the day of admission. The vomitus consisted of yellowish fluid. The patient had been troubled by gas and indigestion which were aggravated by certain foods, such as cabbage. The bowels were constipated; the stools were not clay colored. There was no jaundice. She had lost 25 pounds (11.3 Kg.) in weight in one year. The family physician stated that the patient's husband had a positive Wassermann reaction and was under treatment at this time. On physical examination a tumor was palpable in the epigastrium a little distance to the right of the median line. A clinical diagnosis of gastric tumor was made and surgical intervention advised.

**Report of Operation (Dr. Heyd).**—The liver was enlarged and presented many stellate scars over its superior surface and particularly a marked degree of inflammatory reaction near the round ligament. Apparently there was no liver substance to the left of the round ligament. On the lesser curvature of the stomach was a neoplasm 7 cm. in length extending over the anterior and the posterior walls of the stomach, with a large crater that could be palpated through the stomach wall. It suggested a chronic infiltrative ulcer, except for the fact that there were marked reddening and stippling. Operation consisted of gastric resection and Polya anastomosis. The patient died on the third day. Permission for a necropsy was refused.

**Pathologic Examination.**—The specimen was apparently from the prepyloric and pyloric portions of the stomach. A considerable amount of omentum was attached on the serous surface, and was bound by handlike adhesions to the surface. Within the fat tissue three lymph nodes were felt, each measuring 10 by 5 mm. On section the lymph glands were grayish and soft. The stomach was opened at a line between the lesser and the greater curvatures. It measured approximately 100 by 100 mm. The wall of the stomach measured 10 mm. at its widest point. The submucosa was markedly thickened, edematous and white.

spasm. The patient complained of numbness in the fingers, especially to pin prick, and there were no motor disturbances. There was no swelling of the hand, but it seemed colder than the other and the finger tips were slightly blue. The palm was constantly moist. A deep burning sensation extended from the forearm to the fingers. There was no atrophy. Roentgen-ray examination showed forward rotation of the semilunar bone on transverse axis of about 45 degrees. No other lesion was present.

On April 12, an attempt was made at bloodless reduction and under an anesthetic but was unsuccessful.

On April 19, an open operation was performed. The semilunar displacement of the os magnum was reduced by means of a blunt probe; the semilunar bone was held in proper rotation while pressure was made on the head of the os magnum. Manipulation brought the bones into complete reduction. Splints were applied with the wrist in dorsiflexion and the fingers fully extended. The patient expressed a great sense of relief the next day. At the end of ten days, the splints were removed daily and physiotherapy treatments were given. Function returned rapidly and within two months normal motion was regained, but normal strength did not return for about four months.

A result almost as good as in case 2 was found in one of the same type in which the semilunar bone was removed on the tenth day after injury.

CASE 3.—L. M., a white man, aged 28, had his wrist injured by the backfire of an engine. The bone could not be replaced by the closed method and was removed on the tenth day after the accident by Dr. C. R. G. Forrester in Chicago. I examined him two years later. His complaint was pain after he had played several sets of tennis. He said that his wrist felt as though it were sprained. The wrist and fingers appeared normal, but he had 50 per cent loss of dorsiflexion. All other motion seemed free and painless. The roentgenogram showed absence of the semilunar bone. No arthritis or disturbance of the other bones was present.

In case 4 the bone was not removed until later than in the other cases, and the patient was able to return to the occupation of a steel worker.

CASE 4.—G. M., a white man, aged 21, a structural iron worker, five months previous to admission fell a distance of 20 feet, landing on his outstretched left hand. The diagnosis of a severe sprain was made and a splint was applied. The pain was severe, requiring morphine for relief. A roentgen-ray examination was not made. The splints were left on for six weeks; when they were removed, there was no motion in the fingers or wrist and the pain was still severe. In two weeks, he could move the fingers slightly. The position of the hand was: slight flexion at the wrist, the knuckles depressed and the phalangeal joints flexed more particularly at the terminal joint. All the fingers felt numb, the first and second more than the others. The hand was blue and cold. Dorsiflexion of the wrist remained painful and limited to a few degrees.

On admission Jan. 9, 1922, the wrist was thickened through the anteroposterior diameter. There was marked tenderness in the anatomic snuffbox and over the region of the semilunar bone. There was no depression on the dorsum of the wrist but fulness at the base of the palm. The finger joints were freely movable. The wrist joint had 5 degrees dorsiflexion and 10 degrees flexion. The patient could close the fist only one-third of the normal distance (fig. 9A). The thumb

cells and proliferating fibroblasts. Sparse plasma cells were found. Several areas of necrosis were seen in this superficial part of the submucosa. The lower part of the submucosa was infiltrated by a heavy granulation tissue. However, the individual constituents were separated by edema. There were no tubercles or gumma formations. There was no perivascular arrangement of the infiltrating cells. Only occasional blood vessels in the submucosa showed some infiltration of the wall, which, however, was not marked. The lumen was only slightly narrowed and the elastic coat was without changes. The blood vessels and capillaries were crowded with numerous polymorphonuclear leukocytes.

The muscularis was thickened and edematous, invaded by numerous eosinophils and polymorphonuclear leukocytes. The blood vessels were crowded with polymorphonuclear leukocytes.

Sections from the wall of the ulcer showed similar changes. Here, however, the plasma cells became more numerous. The mucosa was intact, but in numerous places there were hemorrhages and extensive blood extravasation at the basal layer of the mucosa. The muscularis mucosae and submucosa were still thick and edematous, with abundant eosinophils and polymorphonuclear leukocytes, and some vessels showed slight perivascular infiltration of a moderate extent. This purulent granulation tissue invaded the coats of a few blood vessels, with only focal destruction of the elastic lamellae. The muscularis and subserous coat were thickened, edematous and infiltrated with various cells, with a predominance of polymorphonuclear leukocytes. The capillaries were crowded with polymorphonuclear leukocytes.

The lymph nodes showed dilated sinuses with a considerable number of proliferated endothelial cells and lymphocytes. Their architecture was normal.

Sections from the liver showed slight thickening of the Glisson's capsule, which showed infiltration with leukocytes, lymphocytes and areas of hemorrhage. The periportal fields within the liver tissue were markedly thickened and infiltrated by lymphocytes. The liver lobules were quite irregular in their appearance, were compressed and lacked a central vein. The foregoing picture led only to our diagnosis of a superficial ulcer. Because of the fact observed at operation that the left lobe of the liver was missing, a syphilitic origin of this scar was suggested but not definitely proved. Guinea-pig inoculation, culture, direct stains and stains of paraffin sections for various etiologic factors and the Levaditi method gave negative results.

The diagnosis was chronic purulent progressive ulceration, the etiology undetermined.

#### COMMENT

Dr. W. H. Meyer of the department of roentgenology at the New York Post-Graduate Medical School and Hospital stated that of about 18,000 gastro-intestinal roentgen-ray examinations he could be sure of the roentgenologic diagnosis of syphilis of the stomach in only five cases. In the last three years in the combined surgical services of Drs. Erdmann, Peterson and one of us (C. G. H.) of the same institution, our operative removed material permitted us to make a diagnosis of only three undoubted cases of syphilis of the stomach. Because a patient has a positive Wassermann reaction and complains of distress in the stomach

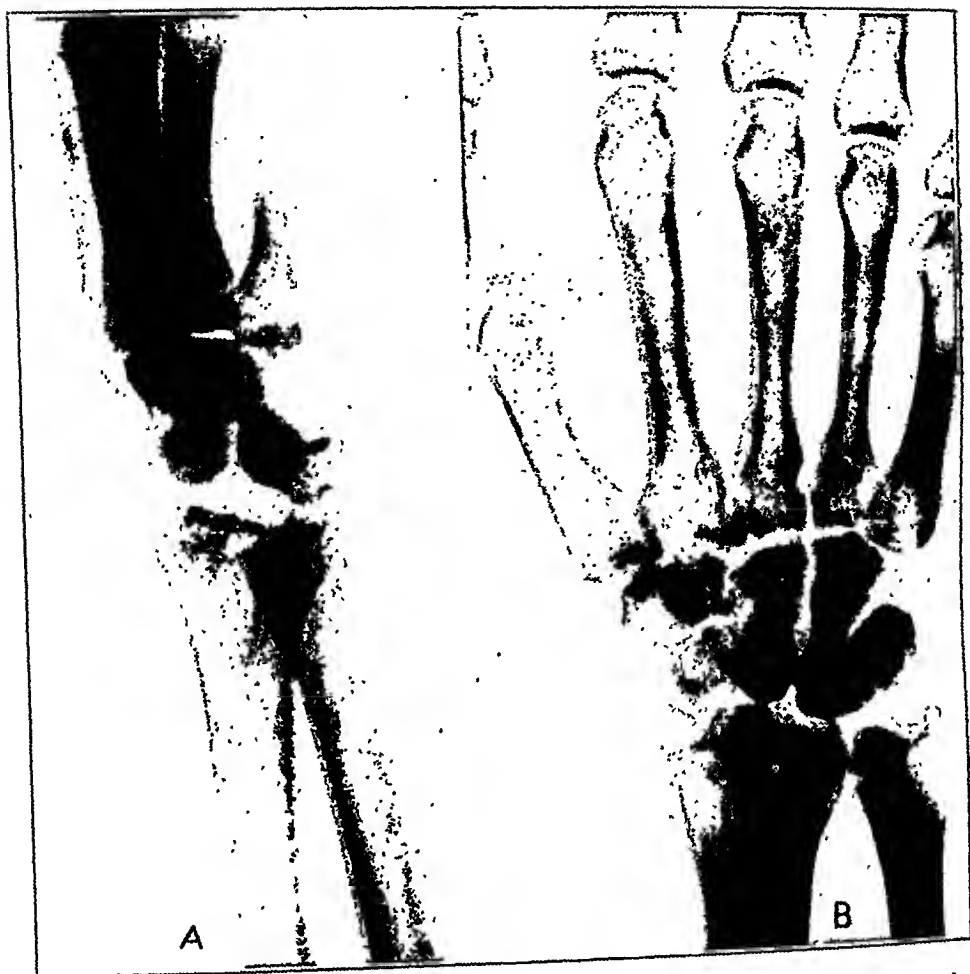


Fig. 5 (case 6).—*A*, appearance before operation, showing entire carpal section displaced backward, with semilunar and proximal fragment of scaphoid close to normal plane of radius; also numerous small fragments. *B*, fracture of scaphoid and styloid of radius; the distal fragment of the scaphoid appears as if it had forced the styloid off the radius and the os magnum is shifted outward. The conical appearance of the displaced semilunar is typical of incomplete rotation.

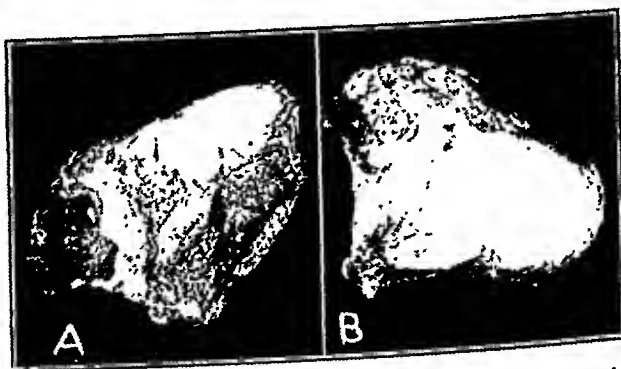


Fig. 6 (case 6).—*A*, radial articular aspects of semilunar and proximal fragment of scaphoid as they were removed with interosseous ligaments intact; *B*, carpal articular aspect of same bone.

case 1 the history of a preceding paralysis and treatment for a spinal condition is interesting as antecedent evidence in regard to the syphilitic stomach.

A consideration of the three reported cases necessitates the following questions: 1. Was the macroscopic appearance of the ulcerations sufficiently characteristic to permit an exact diagnosis? 2. What were the distinctive microscopic features on which a definite conclusion as to the nature of the lesion could be based? The points in common in all three cases are: (1) multiplicity, (2) irregularity of outline, (3) shallowness and (4) thickening of the submucosa with edema. Our three cases differed from each other in some minor features: (*a*) the nature of the margin, steep or overlapping; (*b*) the extent of the infiltration of the submucosa beyond the actual ulceration, and (*c*) the appearance of the base of the ulcer. The gross contrast to any of the common gastric lesions, such as peptic ulcer or ulcerated carcinoma, suggests primarily a diagnosis of syphilis.

The macroscopic criteria for syphilitic ulcer of the stomach, which could be compiled from a survey of the literature, are in accord with the four points mentioned in the first place. However, on microscopic examination case 3 did not exhibit anything that could let one even suspect a syphilitic lesion. Therefore, we came to the conclusion that the macroscopic picture cannot be accepted as sufficiently clear cut to permit even a preliminary diagnosis. Here we are unable to follow Sparmann,<sup>2</sup> who maintains that the macroscopic picture is more characteristic than the microscopic. However, the microscopic features of cases 1 and 2 were those of a syphilitic granulation tissue. The difficulty of a differential diagnosis was limited to tuberculosis or syphilis. The outstanding features in common in both cases were the diffuse and the nodular infiltration of the submucosa, with conspicuous perivascular arrangement and blood vessel changes. Aside from these points in common, however, both cases differed considerably in certain morphologic aspects. These were the origin of nodules within the lymph follicles in case 2, whereas a similar mode of development could not be demonstrated in case 1; the greater number of circumscribed nodules, Langhans' giant cells and predominance of epithelioid cells in case 2, and the presence of nodules within the regional glands and pericapsular tissue in case 2. The severity of the changes in the veins and arteries in case 1, which had produced complete obliteration of the lumen and its replacement by syphilitic granulation tissue, was not present in case 2, although periarterial and endarterial and panphlebitic changes of extensive grade were not absent. On the strength of these morphologic discrepancies, which are in accord

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2. Sparmann, D.: *Deutsche Ztschr. f. Chir.* **164**:136 (June) 1921.

hand seemed displaced somewhat backward as a whole at the wrist joint. There was no paralysis, but he complained of numbness of the first and second fingers, and their tips burned and tingled. There was marked tenderness over the region of the wrist joint.

An operation was performed on April 8. The semilunar bone was replaced and the fracture reduced through an anterior incision. Roentgen-ray examination three days later showed recurrence of the dislocation. On April 21, semilunar and proximal fragment of the scaphoid were removed by a posterior incision. Physiotherapy was begun on May 1. Improvement was slow. The pain was greatly relieved immediately after the operation, but the stiffness was persistent.

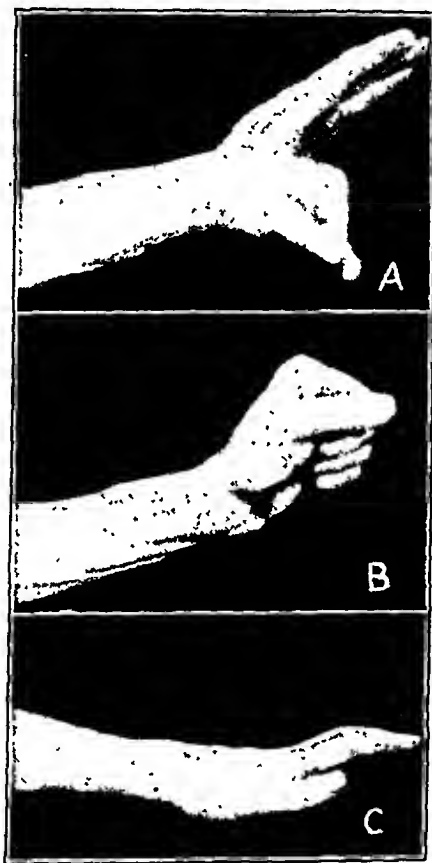


Fig. 7 (case 8).—*A*, extent of motion after three years; *B*, prominence at base of palm; *C*, limitation of extension in wrist and fingers.

December 9, eight months after operation, he had about 50 per cent use of the hand. He could fully close the fingers but had no strength in the grip of the hand. There was about 75 per cent motion in all directions in the wrist joint, but adduction was painful. He was unable to return to his occupation.

Case 8 presents a still different picture. The injury to the carpal bones seems as severe as that in either case 6 or case 7; no operative measures were undertaken, yet the end-result was good function.

CASE 8.—A white man, aged 30, a dairyman, on Aug. 17, 1919, fell 30 feet, landing on his outstretched arms. The next day he had an enormous swelling

## SUMMARY

The three cases of unusual ulceration of the stomach reported were etiologically recognized as (*a*) syphilitic, (*b*) tuberculous and (*c*) non-specific.

The conclusion was reached that, in the absence of a demonstrated etiologic factor, a correct diagnosis could be made only by the combined anatomic, histologic and clinical evidence.



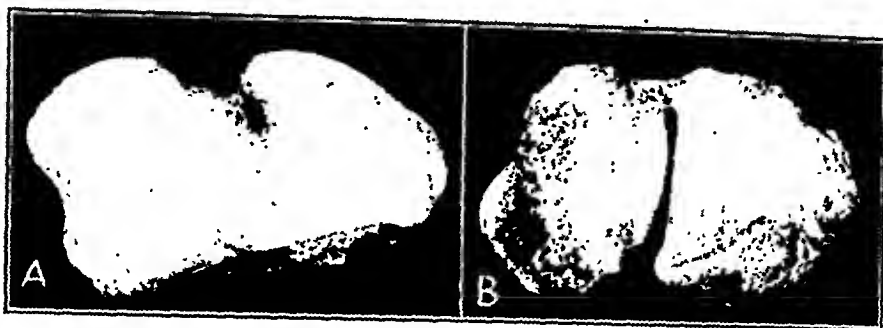


Fig. 10 (case 4).—*A*, radial articular aspect of semilunar bone, showing roughening due to firm fibrous attachment of radius; *B*, smooth carpal articular aspect.



Fig. 11 (case 6).—Appearance three months after the removal of the semilunar bone and fragment of the scaphoid, showing the permanent type neurospastic fixation attitude: *A*, extent of ability to extend fingers; *B*, extent of flexion, and *C*, dorsal view, showing fork prong appearance of fingers and attitude characteristic of neurospastic fixation.

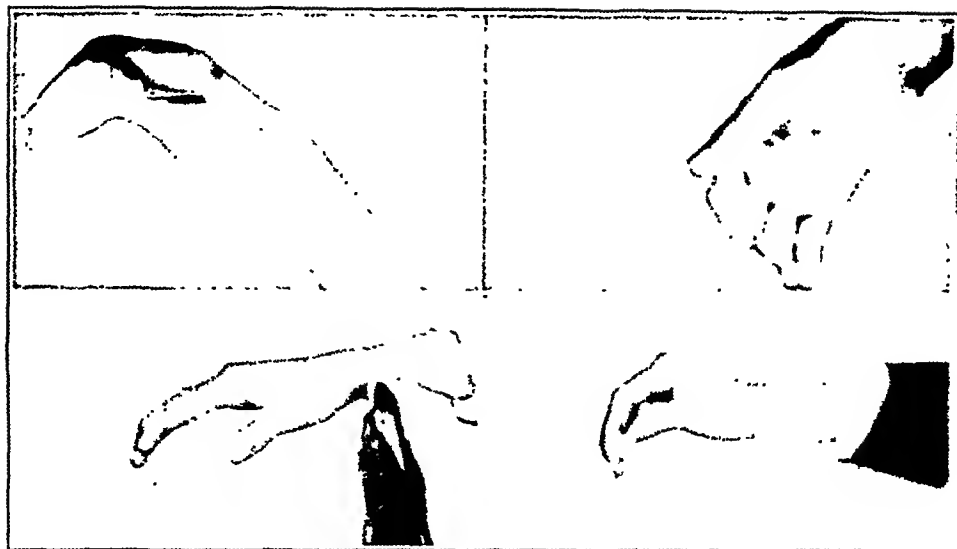


Fig. 1.—Upper part of illustration shows appearance ten weeks after injury, before operation; the thickening of the wrist and the characteristic fixed attitude of the hand should be noted. The lower part of the illustration shows the appearance two years after the removal of the semilunar bone, with limitation of motion in the fingers.



Fig. 2.—Appearance eight weeks after the injury, before operation. *A*, the semilunar bone appears thrust entirely out of its berth, lying perpendicularly in a plane anterior to the radius and the ulna. There is marked calcareous atrophy as well as rotation of the scaphoid on its transverse axis, which hits the proximal fragment upward and backward. *B*, conical appearance of semilunar bone in anterior-posterior view.

At first the fingers are flexed slightly more at the terminal than at the middle phalangeal joints, while the knuckle joints are only a bit flexed or even fully extended or depressed; there is a fulness at the base of the palm and an increase in anterior-posterior thickness of the wrist, which may be mistaken for the deformity of Colles' fracture; examination, however, reveals that this thickness is in the middle of the wrist and not about the radius.

The fingers can be slightly flexed voluntarily, but closing of the fist is impossible. It can usually be closed by passive motion; however, during the first two weeks voluntary extension of the fingers is impossible, and an attempt to extend the fingers or to dorsiflex the wrist by passive motion is extremely painful.

In many cases the spasticity remains mild or gradually relaxes, but often within two or three weeks the pain and stiffness become extremely severe, which gives a definite appearance to the hand. Fixation of the original spastic attitude gradually takes place. The hand becomes somewhat mummy-like in appearance; there is a fixed attitude of slender pronglike fingers and a slightly flexed wrist. To grip the hand gives a cold, stiff feeling as though one had taken the hand of a cadaver. Codman and Chase, in describing one of their cases, say that "the hand looks as though it belongs to another person." The palm is moist, the knuckles are prominent, the skin is glossy and firmly adherent to the subdermal tissue. The fingers cannot be extended fully by passive force, and flexion is limited to a few degrees. Manipulation seems more like the bending of solid rubber fingers than gliding of joints.

Because of atrophy, the fingers seem slender and are separated at their bases, which gives them a fork prong appearance. There is a slight prominence at the base of the palm. The thenar eminence is somewhat atrophied, and the thumb is held close to the forefinger. Atrophy extends up the forearm, rotation being considerably limited.

The outstanding subjective symptom from the beginning is persistent pain of a burning, pressing nature, unrelieved by splints or the position of the hand. Other symptoms are general numbness of the fingers and palm, and sometimes there is a tingling sensation in the first and second fingers on movement of the wrist. The feeling in the fingers is compared by the patients to that of a hand covered with a glove.

I believe that this phenomena is a combination of nerve irritation, joint tension and bone block. As seen in case 1, it may occur in simple dislocation as well as in that complicated by fracture of the scaphoid.

#### PROGNOSIS AND TREATMENT

Various authors seem to differ widely in their reports. Some warn of a grave prognosis; others say nothing of serious possibilities. Some report cases in which late reduction is satisfactory and describe special

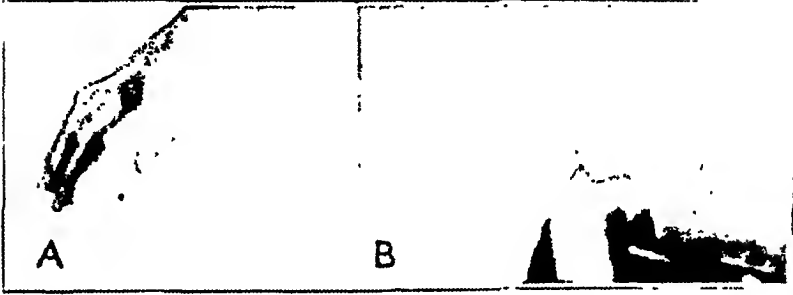


Fig. 4 (case 2).—*A*, appearance three weeks after injury, showing typical neurospastic fixation attitude; *B*, appearance showing normal function three months after open reduction.

A few months after the first patient was discharged the second patient was seen. The results in this case were surprisingly good.

function. When the whole of the fractured scaphoid and semilunar bone were removed, the results were reported as excellent, satisfactory, poor and improvement of the patient.

*Opinions.*—Adams<sup>3</sup> advises: "Removal where limitation of flexion and extension would interfere with work." Magnuson<sup>7</sup> says: "Removal gives extremely satisfactory results." Codman<sup>4</sup> and Chase: "If one cannot reduce, excise. Best to excise proximal half if scaphoid is fractured." Cohen<sup>8</sup>: "Removal gives good function." Knapp<sup>5</sup>: "Excision is last resort and is practically obsolete." Speed<sup>1</sup> advises: "Removal if unreduced at one week. If scaphoid is fractured, removal of whole bone." Stern<sup>9</sup>: "If one can't reduce, remove as early as possible."

#### LATE REMOVAL OF BONE IN CASES IN WHICH FIXATION AND DEGENERATIVE CHANGES ARE MARKED, SIX CASES

*Time After Injury.*—The time after injury may be from ten weeks to six years.

*Result.*—Elimination of pain was mentioned in two cases; otherwise, little or no improvement was noted.

*Opinions.*—Codman and Chase<sup>4</sup> say that removal is indicated for the relief of pain. This does not improve stiffness. Speed<sup>1</sup> says that removal eliminates pain.

#### CASES IN WHICH TREATMENT WAS NOT GIVEN

*Results.*—In every case a severe permanent loss of function is reported. One patient had pain, stiffness and numbness at six years; one could play polo after four years, but had 50 per cent limitation of wrist motion. All had pain for many months.

*Opinions.*—Adams<sup>3</sup> says: "May leave alone if good flexion or extension and if articulation with os magnum head is not displaced." Codman and Chase<sup>4</sup>: "Removal should have been done in each of our cases." Kleinberg<sup>10</sup> states: "Left alone because improvement seemed progressing satisfactorily."

#### SUMMARY

The experience in my own cases and in those recorded in the literature leads to the following conclusions:

*A. Simple Dislocation of the Semilunar.*—1. Reduction can usually be accomplished by manipulation within the first three or four days, and complete return of function can be expected.

3. Adams, J. D.: Displacement of Semilunar Carpal Bone, *J. Bone & Joint Surg.* **7**:665-681 (July) 1925.

4. Codman and Chase: *Ann. Surg.* **51**:863 (March-June) 1905.

5. Knapp, H. B.: Dislocation of Semilunar Carpal Bone, *J. A. M. A.* **79**:1192 (Dec. 9) 1922.

6. Davis: Treatment of Dislocation of Semilunar Carpal Bone, *Surg. Gynec. Obst.* **37**:225-229 (Aug.) 1925.

7. Magnuson, P. B.: *Internat. Clin., Philadelphia* **3**:124-127, series 30, 1920.

8. Cohen: *Ann. Surg.* **73**:621 (May) 1921.

9. Stern, W. G.: Dislocations of the Carpal Semilunar Bone, *J. A. M. A.* **75**:1389 (Nov. 20) 1920.

10. Kleinberg, S.: Dislocation of Carpal Scaphoid and Semilunar Bones, *J. A. M. A.* **74**:312 (Jan. 31) 1920.

was unaffected. The hand was cold and blue and there was no tingling. Roentgen-ray examination showed the semilunar bone rotated forward on the transverse axis about 45 degrees, with the head of the os magnum in a position of subluxation back of it. There also was fracture of the posterior border of the radius, which limited the flexion and extension of the wrist. The semilunar formed an extension of the radius rather than a part of the carpal group. Reduction was impossible, because when the semilunar was freed from its adhesions it was entirely enucleated. It was also impossible to secure sufficient space for the semilunar bone between the head of os magnum and the radius. The day after the operation the patient said that it was the first time he had been free from pain since the injury. A splint was applied with the wrist in 15 degrees extension for ten days; then physiotherapy was used. Four weeks after the operation he had 10 per cent more motion in the wrist and fingers than before the operation. At the end of two months, he was able to close the fingers into the palm, and the wrist movement was about 10 degrees dorsiflexion and 20 degrees palmar flexion (fig. 913). Nine months after operation, the patient returned to his position as a steel worker. He has full strength in his grip. There is 10 per cent loss of dorsiflexion. The other movements seem normal.

A result as good as that in case 4 was obtained in case 5, in which the bone was reduced after being neglected for three months.

CASE 5.—H. W., a man aged 21, had a heavy weight thrown on the tip of the fingers, forcing the hand backward, at the same time that the elbow was caught and held firmly. He was treated for a sprain, and splints were applied for four weeks. The pain was constant and medicine did not relieve it. On removal of the splints, the fingers could not be closed and he had little motion in the wrist joint. On admission three months after injury, his chief complaint was pain and stiffness. The wrist was thickened anteroposteriorly, and there was a prominence on the wrist at the base of the palm. There was no loss of sensation, but he stated that the middle and fourth fingers felt numb. Roentgen-ray examination showed the semilunar bone rotated forward on its axis, with the head of the os magnum back of its posterior horn. An open operation was performed with the expectation of removing the bone. A palmar incision was made; after the bone was loosened from its fibrous bed, it became possible to reduce it, and the wound was closed. Roentgen-ray examination the next day showed the bone again dislocated, in its former position. Ten days later, through a dorsal incision, the bone was again reduced; this time it was maintained by a strand of cotton hooked in a notch under the posterior horn of the semilunar bone and inserted into the dorsum of the radius. There was considerable thickening of the wrist for ten days after the operation. The stiffness decreased rapidly, but the pain, which was greatly relieved at first, was persistent. The patient secured a position as a waiter three months after the operation. Six months after the operation the contour of the hand and wrist were normal, there were 50 per cent of extension, 75 per cent palmar flexion and 75 per cent rotation. Forceful extension was painful. He had about 50 per cent of normal strength and was still in good health.

Another type of case is that in which the scaphoid is fractured. The prognosis under all circumstances in such cases is poor.

CASE 6.—L. R., a white man, aged 32, a structural engineer, fell from a beam on July 4, 1921, stating that six days previous to the fall he had been on his feet, landing on his outstretched arms at 16 feet. He had been carrying a

# THE CAUSE OF POSTOPERATIVE RUPTURE OF ABDOMINAL INCISIONS \*

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There are few things more disturbing than the postoperative rupture of an abdominal incision. This unusual disaster does not occur for a number of days, perhaps a week or more, following an operation; often when everything appears to be progressing favorably and the safety of the patient seems assured. The subject is frequently mentioned in surgical writings, but I am not aware that a satisfactory explanation has been given. The usual ways of accounting for the phenomenon are:

1. *Giving Way of the Sutures.*—This may occur by breaking, cutting through, or too early absorption. This seems likely at first thought; but when one remembers the thousands of instances in which all sorts of sutures are used in all sorts of ways without trouble, the explanation seems inadequate.

2. *Unusual Strains.*—These may be caused by vomiting, coughing or distention. Such strains, however, are always occurring, and yet rupture of an incision is rare.

3. *Infection of the Wound.*—This not only fails to explain the numerous instances of rupture without infection, but it also does not take into account the cases in which suppuration occurs, perhaps with extensive sloughing, and yet the wound remains intact, even under great strain. Furthermore, suppurating wounds not infrequently are packed with gauze, no sutures being used except in the peritoneum, without trouble resulting; and there are even those who do not use gauze at all, leaving the external wound wide open—in fact, something like this occurs when deep suppuration takes place, separating the muscles and fascia and leaving only the peritoneum below and the skin above the resulting abscess.

4. *Failure of the Healing Process (Predisposition," Age, Disease, Etc.).*—This seems to be rather begging the question, because ruptures often occur in healthy patients whose healing powers are unquestioned; and it often occurs in part of the wound while the remainder unites perfectly. And again, when a ruptured wound is reunited, healing frequently takes place without difficulty.

Recently, Weber<sup>1</sup> has attempted a physicochemical explanation by assuming that the underlying cause of rupture is an increase in the

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\* Read in part at a meeting of the Western Surgical Association, Dec. 19, 1925.

1. Weber, M.: *Zentralbl. f. chir.*, Jan. 3, 1926, p. 277.





The foregoing hypothesis is supported by various observations:

1. Ruptures of incisions are more often seen in the central and lower part of the abdomen, where the omentum is most in evidence, rather than in the extreme upper part of the abdomen, although the strain of vomiting and distention is equally great in both situations.

2. I have always found a tongue of omentum in the ruptured wounds which I have seen, and its swollen condition and adhesions indicated that prolapse probably occurred immediately following the operation and not at the time of rupture. As other surgeons have told me of similar observations, I am convinced that it is a common experience.

3. There is often evidence that the beginning of a rupture occurs quite soon after the operation, such as tumefaction, the leakage of bloody serum between the stitches, or the presence of unusual discomfort, with nausea, vomiting, distention, and partial or complete intestinal obstruction. Such occurrences probably are produced by the incarceration of a tongue of omentum, or a portion of bowel, followed by swelling and serous exudation.

4. Every surgeon has observed how the omentum tends to protrude through a stab wound of the abdomen, and with what exasperating pertinacity it crawls between the stitches in closing a laparotomy incision, and one readily can realize how this tendency would be augmented by postoperative vomiting and distention; in fact, I have seen such a protrusion occur from vomiting before the external wound was closed.

5. The certainty with which ruptured wounds may be reunited, although the suturing may be imperfect and the wound edges apparently in poor condition for healing. This is due, I believe, to the fact that the swollen and internally adherent omentum can no longer enter the wound.

• If, then, we assume that postoperative ruptures occur from within outward, and not from without inward, and that the wedging of the omentum through a gap in the peritoneal suture line is an important factor, it is evident that the danger can be lessened by greater care in closing the peritoneum. • If interrupted sutures are used they should be placed very close together. If a running stitch is employed, the spacing should be short, it should be pulled tight and frequently back-stitched and locked. Ordinary over-and-over sutures are often hastily and loosely inserted, sometimes with gaps of as much as half an inch (1.2 cm.) or more. Their inadequacy may be demonstrated during an operation by passing a finger beneath the partially closed incision, especially if the suture line is relaxed by bending the patient's thorax forward—a position that frequently is assumed in bed.

Although complete ruptures of abdominal incisions are rare, subcutaneous ruptures are not uncommon. By these I mean instances in which, although the skin remains united, there is failure of union of



This, of course, does not mean that hernias may not also be due to other causes, such as the sloughing of fascia.

Recently some experiments on dogs have been conducted for me in the department of pathology of the University of Colorado School of Medicine by J. W. Jackson and W. C. Black, under the direction of Prof. Ralph G. Mills, who will present in a separate article a more detailed account of his findings and deductions. Fifteen laparotomies were done, the incisions being closed in the usual manner, in layers, with chromic catgut throughout. In each instance a tongue of omentum was brought into the wound between the muscles, but beneath the united fascia.

In a number of dogs, especially when the amount of omentum was large and partly or completely strangulated, there was a failure of union, not only of the muscles, but also of the overlying fascia. This was due largely to the greatly swollen omentum, but also to the presence of a considerable quantity of thick lymphlike fluid, which formed a sort of cyst. Owing partly to the presence of this fluid, which I believe to be a factor, nonunion and separation of the tissues existed for some distance on either side of the omental plug (figs. 1 and 2).

It also was noticed that when strangulation of the omentum occurred, infection and suppuration were more likely to result, which increased the tendency to separation of the tissues.

Although no actual wound ruptures occurred in this series of experiments, the stage was apparently set for such an event, which might easily have taken place if the proper strain could have been produced at the proper time. It also was quite evident that the conditions often were favorable to the subsequent production of ventral hernia from subcutaneous wound rupture.

#### SUMMARY

As an explanation for the postoperative rupture of abdominal wounds, the hypothesis is offered that it often results from an inadequate closure of the peritoneum. Between the loose stitches the omentum (or occasionally the bowel) forces itself, and in swelling acts as an expanding wedge which forces the tissues apart and prevents proper union, the process being aided by serous exudation or, perhaps, suppuration. A rupture may then be precipitated by the strain of vomiting or distention, especially when the fascia is involved. Massive adhesions and many postoperative hernias are similarly explained by subcutaneous wound rupture, which is much more common than complete rupture.

on the back of the wrist and a small symmetrical enlargement at the base of the palm. The pain was severe and morphine was required to relieve it. The tips of the fingers were "drawn" into a flexed position but the knuckle joints were not flexed. When an attempt was made to straighten the fingers, the tendons became prominent in the palm of the hand. There was slight voluntary motion in the fingers, but effort was painful. Roentgen-ray examination was made, but the diagnosis was uncertain. The consulting physicians disagreed, some stating that the wrist bones were crushed, others that there was a fracture of the scaphoid bone. The arm was placed in a splint for three weeks but the pain was continuous and the patient was given hypodermic injections daily for relief. When the splints were removed, the hand was greatly stiffened and had slight voluntary movement. The fingers were numb, especially the first and second, but there was little or no swelling. He treated and massaged his own hand, but after nine months he could not grip a lead pencil tight enough to hold it. The pain was annoying during all this time, and even at the end of two years the chief complaint was pain and weakness.

On admission, June 1, 1921, roentgen-ray examination showed dislocation of the semilunar bone and fracture of scaphoid, with a great amount of calcareous atrophy (fig. 8). An open operation and removal of the displaced parts was advised but refused. At this time, there were no adhesions in the fingers, but grip was weak and the wrist movement was limited to 50 per cent of normal. There was a large prominence at the base of the palm and a slight bony prominence on the back of the wrist in the midline (fig. 7). When pressure was made at the base of the palm, a tingling sensation was produced in the fingers and forced extension at the wrist was painful. The patient made his living dairying and was advised to use his hand for milking. On examination, March 1, 1923, practically normal function had returned, but the prominence was still present at the base of the palm and pressure at this point produced a tingling sensation. The wrist was not as strong as normal, and he sometimes dropped things easily. Roentgen-ray examination showed the bones to be in about the same condition as on June 1, 1921, except that calcareous atrophy had disappeared in all the bones except the scaphoid fragment and the semilunar bone.

#### NEUROSPASTIC FIXATION ATTITUDE

Each of these eight cases presents a different phase of the subject, yet there are many points common to all which may be considered characteristic of the injury.

In the first place, there is a common attitude and appearance of the hand, wrist and fingers in all cases. The illustrations accompanying the articles in the literature also show the same characteristics. Several authors speak of "a slight fork deformity" and others mention a "claw-like hand." In the semilunar cases, however, the surgeon is dealing with an attitude based on physiologic disturbances rather than on a deformity due to anatomic changes, as in the case of Colles' fracture. At first the attitude is of a spastic nature. Within one or two weeks, the attitude may become fixed, and as time goes on without treatment, this fixation may become more or less permanent stiffness with progressive degenerative changes. For convenience and as a descriptive term, therefore, I suggest the attitude be designated as that of "neurospastic fixation" of the hand.

cases, all bone cells of the compact bone were necrotic, while the cancellous tissue still showed many living cells. He explains these observations by the thickening of the intercellular substance which, with decreasing circulation, offers an unsurmountable resistance to the circulation. These conditions are similar to those in transplanted bone and in compact bone tumors; similar changes may be seen also in certain pathologic conditions.

*Avitaminosis and Healing of Fractures.*—Israel<sup>40</sup> has made experiments in order to study the influence of scorbutus on the healing of fractures. Substituting carrots in the food of rabbits by citric acid of various concentrations, he found a reduction of the formation of callus in direct proportion to the dilution, and when citric acid was not given no callus was seen. Vitamins were withdrawn at a time when a definite amount of callus had already formed; callus continued to grow at first, but during the tenth week, spontaneous fracture took place. This in turn healed when a diet rich in vitamins was given. Similar delay in union of the fractures seems to take place in severe general infection, tuberculosis and also in pregnancy. Bier states that in cases of poor union of fractures he gives the patient half a pound of unpeeled carrots, orange juice salad and one-eighth pound of honey. He recalls a remark of Billroth, that pseudarthrosis generally heals after the patients have been removed to their homes, indicating the difference in vitamins in hospital and in home diet in Germany.

#### BONE, JOINT AND TENDON SURGERY

*Tendon Surgery.*—Harmer<sup>41</sup> reports a series of cases of tendon and nerve repair. The group includes 112 cases, involving chiefly the hands and wrists. The article emphasizes the principle of immediate active motion of sutured tendons without splinting. On the day of the operation, when sufficiently recovered from the anesthetic, the patient is personally instructed in exercises to move each phalanx of each finger. He is told to repeat these exercises every hour, and at some time every day he is personally supervised in these movements by the surgeon. The results as shown by photographs are excellent.

Mayer,<sup>42</sup> speaking of traumatic division of the extensor tendons in which primary suture of the tendons is contraindicated because of infection or extensive trauma to the adjacent tissues, states that with suitable technic tendon transplantation can be performed successfully at a later date. The tendon of the extensor communis digitorum of the index finger is the one that can be used most easily for transplantation. He lays much emphasis on the use of a special kind of tendon stitch. He

40. Israel, A.: *Zentralbl. f. Chir.* 53:1414 (May 29) 1926.

41. Harmer, T. W.: *Boston M. & S. J.* 194:739 (April 22) 1926.

42. Mayer, Leo: *J. Bone & Joint Surg.* 8:383 (April) 1926.

instruments for accomplishment of the operation, yet others assert that late reduction is not rational because of traumatic arthritis and absorption of bone structure, due to nutritional disturbances.

One reason for such a divergence of opinion on the part of those who have reported cases is no doubt that the clinical characteristics vary a great deal in respect to the severity of nerve and joint complications; another is that only a few cases are seen in any private practice.

As an attempt to formulate more reliable conclusions on which to base prognosis and treatment, I have made a summary of cases in the literature in which sufficient data were recorded to compare methods of treatment, results and opinions of authors.

The comparison is made from ninety-four cases recorded by twenty-nine different authors. Of this number, twenty-six were cases of closed reduction, seven of open reduction, forty-nine of early removal, five of late removal and seven cases in which the patient was untreated.

#### CLOSED REDUCTION, TWENTY-SIX CASES

1. *Time After Injury.*—The dislocations were reduced in nearly all cases within two or three days after injury. One was successful at four weeks. Three were complicated by a fractured scaphoid, two of which were reduced within forty-eight hours and the other at five days.

2. *Results.*—All patients report a complete return of function.

3. *Opinion of Authors.*—All agree that reduction can be accomplished best within a few hours after injury. Codman and Chase advise an attempt at a closed reduction as late as four weeks.

#### OPEN REDUCTION, SEVEN CASES

1. *Time After Injury.*—The shortest time after injury at which reduction was performed was six days. In the other cases, it was done from three weeks to three months later.

2. *Results.*—In three cases good function was obtained. Four patients had persistent pain and impairment of function. One of these had a fractured scaphoid; another had severe pain. The neurospastic fixation was definite, and three operations were performed.

3. *Opinions.*—Adams<sup>3</sup> says: "danger of traumatic arthritis, end results unsatisfactory." Codman<sup>4</sup> and Chase: "If closed reduction fails, try open." Knapp<sup>5</sup>: "Late reduction successful." Speed<sup>1</sup>: "Reduction after six days not advisable because of absorptive changes and traumatic arthritis." Davis<sup>6</sup>: "Can reduce even late cases with special skill."

#### EARLY REMOVAL OF BONE AND REMOVAL IN CASES IN WHICH NEUROSPASTIC FIXATION IS NOT OF A PERMANENT NATURE, FORTY-NINE CASES

Twenty of the forty-nine cases are those of Speed. The time after the injury ranged from six days to nine months. The scaphoid was fractured in several cases and dislocated in one. Removal of the whole scaphoid and the semilunar bone was mentioned in six cases.

*Results.*—The earlier the removal the better the results reported. No one reports perfect return of function. There were excellent results in one case in which removal was done after nine months. Several patients report satisfactory

*Osteoperiosteal Grafts for Spinal Fusion.*—H. and Y. Delagenière<sup>45</sup> have been employing osteoperiosteal grafts in fusion operations of the spine for Pott's disease with good results. The technic is relatively simple, and this is its advantage over other methods. Massive bone transplants lose their vitality, whereas osteoperiosteal grafts survive and are therefore a better aid to fusion. The operation is performed with the patient lying on the right side. The muscles are retracted laterally and the laminae exposed and denuded of periosteum. With the chisel, long strips of periosteum lined with a thin but even layer of bony tissue are cut from the internal surface of the tibia. These are laid down in the vertebral gutter, with the bony surface against the laminae and the spinous processes. The muscles are replaced, covering the grafts, and the aponeurosis is sutured. A small drain is inserted. Following the operation the patient is kept flat in bed, but without apparatus. At the end of two months, a plaster jacket is applied and the patient is allowed out of bed. Jacket fixation is maintained for about six months. Three cases of successful operation in adults are reported.

[ED. NOTE.—Some of us have been employing osteoperiosteal grafts in operations for spinal fusion for several years. The Hibbs method of fusion has been used, with the osteoperiosteal graft added for additional security. The results were impressive in one such case in which a second operation had to be performed, but not because of failure of fusion. On the side where the graft had been laid there was a large thick sheet of bone, much thicker and more solid than on the other side, where no graft was used to reinforce the fusion. If the osteoperiosteal graft alone would suffice without any other fusing procedure, it would go far toward simplifying the operation and removing its risk. We consider drainage of these wounds unnecessary.]

*Correction of Deformity in Bony Ankylosis of Hip Joint.*—Abbott and Jostes,<sup>46</sup> realizing the great risk of displacing the bony fragments in attempting to correct cases of extreme deformity of the hip joint with ankylosis by the usual method of subtrochanteric osteotomy and plaster fixation, have employed a different procedure, with entirely satisfactory results. Following the osteotomy, they put the leg up with traction in a Thomas splint, not trying to obtain correction of the deformity until the end of about four weeks. At this time, the fragments are united by firm but moldable callus. Extension is then applied to the unaffected leg in a position of wide abduction to control tilting of the pelvis. Then, gradually, the contracted hip is brought down into the desired position.

45. Delagenière, H. and Y.: *Archives franco-belges de chir.* 29:21 (Jan.) 1926.

46. Abbott, L. C., and Jostes, F. A.: *Surg. Gynec. Obst.* 42:274 (Feb.) 1926.

2. In cases in which removal of bone is done within two or three weeks or in which there is mild neurospastic fixation, good function will result, but at least some permanent weakness will remain.

3. Open reduction under the same circumstances promises as good a return of function as removal. There is, danger, however, of traumatic arthritis.

4. Untreated patients have from 25 to 75 per cent permanent disability.

5. Open reduction after several weeks or in cases in which neurospastic fixation is severe should not be attempted, even though in many instances it can be accomplished. Removal is better.

6. Removal in late cases with severe fixation and degenerative changes usually will relieve the pain to a considerable degree. Improvement in function is slight.

*B. Fractures of the Scaphoid.*—1. Severe traumatic arthritis is so likely to occur in these cases that closed or open reduction is dangerous. If not accomplished within a few hours after injury, excision is therefore indicated.

2. Removal of the semilunar and whole scaphoid bone seems to give as good results as those secured in cases in which the proximal fragment only is removed and is the method of choice.

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#### CORRECTION

Dr. Gabriel Tucker asks that attention be called to the following corrections in his article, "Technic of Bronchoscopic Introduction of Bismuth Subcarbonate and Iodized Oil 40 Per Cent, for Pneumonography" (Arch. Surg., January, Part II, 1927):

The reference at the end of the first paragraph, page 175, should be to figs. 5 and 6.

The reference in the fourth line from the bottom on page 181 should be to fig. 4, instead of to fig. 6.

The instrument illustrated at the top of page 182 was devised by the author, Dr. Tucker, and mention of this should be included in the legend to fig. 7.

Dr. Tucker also calls attention to the fact that the stenographic report of his discussion on the papers by Drs. Singer, Tucker, Ballou, Stewart and Archibald (Arch. Surg., January, 1927, page 216) is incorrect, in that the negative was omitted; the twelfth sentence in the paragraph should read: "In our clinics, we do not use the bronchoscope in tuberculosis unless there are special indications."



to 8 cm. Lateral deviations were not observed. Unilateral varicose veins have been a late complication, seen in almost all the cases. These seem to have a double origin, the presence of numerous scars from old draining sinuses and the absence of normal muscle contraction. On the resected side, the foot was smaller and shorter by from 15 to 20 mm. The patients have been walking with the foot in equinus, and this has led to a cavus type of foot with anterior callus formation. Although the static conditions have been changed, no painful symptoms or limitation of motion were found in the hip. In three cases, the roentgen-ray examination showed a certain degree of coxa valga, these patients being 15, 14 and 20 years of age at the time of the operation.

[ED. NOTE.—In cases of tuberculous disease no results can be considered end-results until after the lapse of a considerable number of years. The foregoing report is of interest because it represents the first attempt of which we have knowledge to obtain the entire life history of a patient following operation. The study of the functional result also is valuable. An investigation along similar lines of groups of patients treated at some of the large clinics for heliotherapy is much needed. Only by this means can we reach a conclusion as to the place of operative surgery in the treatment of joint tuberculosis.]

*Surgical Treatment of Flat-Foot.*—In cases of severe contracted flat-foot, Meyer<sup>49</sup> has obtained good results by freezing the peroneal nerve for two or three minutes with ethyl chloride. The nerve is exposed above the head of the fibula. By this means the peroneal muscle group is paralyzed for a period of about six months, and during this time the feet are treated by massage, exercise and foot plates. The method has proved satisfactory in forty-nine cases, and in all the function of the nerve has been recovered in from five to seven months. Even in bilateral cases the function of the feet was so little embarrassed that the patients were able to resume their work almost immediately following the operation.

Schulze-Gocht<sup>50</sup> does not agree with the view that the action of the peroneus brevis is similar to that of the peroneus longus, and that both are bad mechanical factors in flat-foot. He points out that the latter muscle draws the midportion of the foot outward, but the forefoot inward, while the peroneus brevis raises the outer border of both tarsus and metatarsus. In the surgical treatment of flat-foot, the latter muscle should be eliminated while the former should be reinforced. He therefore exposes the peroneal tendons above the external malleolus, sutures the short peroneal to the long peroneal tendon and cuts the tendon of

49. Meyer, Hermann: Beitr. z. klin. Chir. **135**:150, 1925.

50. Schulze-Gocht: Arch. f. Orthop. d. Unfallchir. **24**:32, 1926.

acidity of the tissues, due to some form of systemic intoxication. Even if it were admitted that this might explain the ruptures that occur in connection with ileus and malignant tumors (which he emphasizes) it would afford no solution for the numerous instances in which no general intoxication exists, or in which the rupture occurs in a portion of the wound only. As he admits, this theory necessitates, in order to explain the prompt healing that occurs following secondary suture, the rather unsatisfactory assumptions that the acidity has been overcome, or that substances are generated in the blood which favor the healing process (Epstein), or that in some way the primary wound has exerted an influence on the sympathetic nervous system which favors the secondary healing (Dschaneldige).

5. *The Formation of a Hematoma.*—This might weaken a wound and increase the danger of rupture, but its expansile pressure could hardly be great enough, arising as it does from small vessels; to separate the firmly united fascia and peritoneum. In order to cause trouble, the hematoma would have to be large; but I have never seen evidences of even a small one in a ruptured wound, although a certain amount of bloody serum often is present.

While any one or several of the things mentioned may play a part in the giving way of abdominal incisions, they often do not appear to be the main factors. In many instances I believe the primary cause to be inadequate closure of the peritoneum, leaving a gap in the suture line. Through this opening the omentum forces itself, perhaps between the muscles, and even at times through the overlying fascia, which likewise may be imperfectly united. This omental protrusion not only interferes with immediate union of the wound, but as it becomes congested and swollen by strangulation it acts as a sort of expanding wedge, the effects of which are augmented by an accompanying serous exudation, the ultimate result being separation of the tissues and weakening of the incision. Any sudden strain, from coughing, sneezing or vomiting, may now precipitate a rupture, especially if infection has complicated the situation and sufficient time has elapsed to permit of partial absorption of the catgut sutures. Occasionally, as I have seen, it may be the bowel that insinuates itself between the stitches, or perhaps bowel and omentum together.

It is evident that the acceptance of this explanation would mean that the foundation for the rupture of an incision is laid immediately following an operation, and that there is a gradual increase of the trouble until disaster results, provided a number of more or less important factors are coincidentally favorable.

*Age of Fractures.*—In an effort to decide whether it is possible to determine the age of a fracture by its roentgenologic appearance, Andrei<sup>53</sup> has made a study of 269 cases of fracture of the shafts of the long bones and of the phalanges. His conclusions are as follows. 1. In simple diaphyseal fractures without displacement, the first modification of the appearance is a blunting of the margins and of the bony spicules, which becomes evident at the end of the second week. The callus begins to appear between the sixteenth and the twentieth days after the injury. It becomes clearly delineated at the third or fourth month, and acquires the opacity of a normal bone between the eighth and tenth month. During the first year, the callus remains free from lamellar structure. The reconstruction of the lamellar system begins at the thirteenth or fourteenth month, and is well advanced at the end of the second year. The line of fracture disappeared from the sixth to the eighth month after injury, and reappears later as a line of increased opacity. At the end of the second year, although there has been a conspicuous reduction in the size of the callus, there always remains a trace of it in the form of a thin, opaque layer that thickens the bone. 2. In diaphyseal fractures with displacement of the fragments the blunting of the margins and spicules of the bones appears at the end of the second week. The callus begins to be evident in the third or fourth week. It becomes delimited from the contiguous tissues later than in other types of fracture—that is, toward the sixth or seventh month—and contemporaneously regains the opacity of normal bone. It undergoes a process of reduction less than in fractures well reduced, and the reconstruction of the bony structure is not made at any fixed period. 3. In the fractures of the phalanges, of the metacarpals and of the metatarsals, a blunting of the margins and of the spicules is seen at the end of the first week. A few days later, and in general before the end of the third week (sometimes even at the beginning of the second week), callus appears in the form of a delicate white cloud. At the end of the fourth month it is clearly delimited, and toward the sixth or seventh it regains the opacity of normal bone. Even in these fractures, the callus remains free from lamellar structure during the first year after injury. This structure appears at the thirteenth or fourteenth month and is more or less advanced at the end of the second year. This line of fracture disappears between the sixth and eighth months, to become evident later in the form of a bone cicatrix.

*Local Anesthesia in the Reduction of Fractures.*—Cohen<sup>54</sup> advises the more general use of local anesthesia for the reduction of fractures. The method employed has been one of local infiltration at the site of the break, and the experience covers a period of two years, during which

53. Andrei, O.: *Chir. d org. di movimento* 10:255 (Feb.) 1926.

54. Cohen, Ira: *J. A. M. A.* 86:1896 (June 19) 1926.



Fig. 1.—Abdominal incision in a dog: Separating the muscles is a partially strangulated and swollen plug of omentum, above which may be seen a cavity which was filled with serous exudate. Although the fascia had been united above the omentum, it is evident that its union has been interfered with and the strength of the wound seriously impaired. (Prof. R. G. Mills, Pathologic Laboratory, University of Colorado School of Medicine, Experiment 13.)

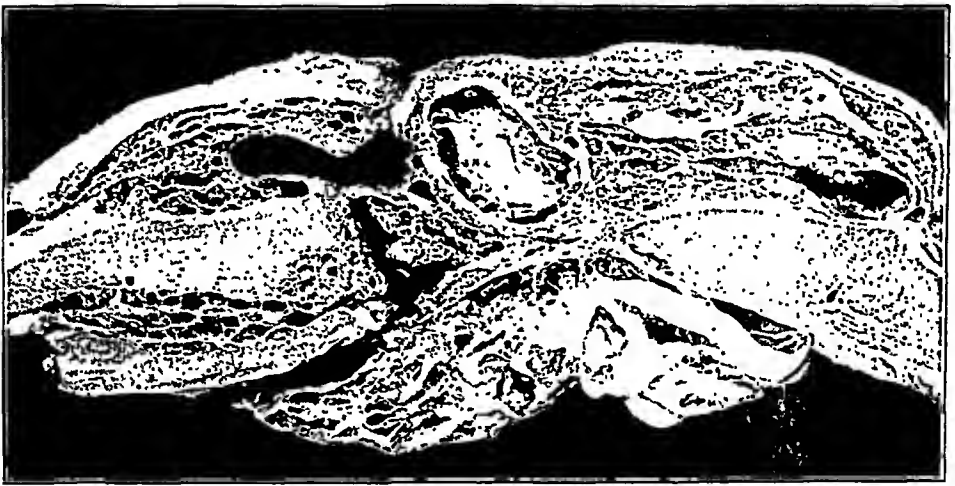


Fig. 2.—Plug of omentum lying in a cystlike cavity originally filled with fluid. (Prof. R. G. Mills, Pathologic Laboratory, University of Colorado School of Medicine, Experiment 14.)

either the peritoneum or of the peritoneum plus the muscles, or of both of these plus the overlying fascia. The omentum, I believe, plays just as important a part in these occurrences as it does in complete rupture, which accounts for the firm omental adhesions so frequently found in secondary operations. If the muscles, and particularly the fascia, are involved, a ventral hernia may result, in close relation to which adherent omentum usually is found, as I am sure most surgeons have observed.

cases were more favorable in every way. The reconstruction operations of Brackett and Whitman were carried out in six other cases, with good results in all. In the latter group, however, there was more residual stiffness than in the former group, and the function, although satisfactory, was by no means as good. The duration of the nonunion is no criterion in selecting the type of operation. Some of the best results from the bone grafting operation were obtained in cases in which the nonunion had existed for from two and one-half to three years. The indications for the operation are considered to be a good state of health, considerable disability and the persistence of a sufficient amount of the neck of the femur.

*Fractures of the Os Calcis.*—Conn<sup>58</sup> believes that fractures of the os calcis can be classified into five groups according to the character of the predominating deformity: (1) eversion of the calcaneum, resulting in a more mesial deflection of the weight-bearing line; (2) upward displacement of that portion of the posterior tuberosity serving as the attachment of the tendon of Achilles; (3) impactions resulting in shortening and upward displacement of the posterior tuberosity without separation of the tendon of Achilles; (4) serious distortion of the articular surfaces; (5) those cases in which by reason of the location or because of the destructive comminution, nonunion is impending or present. Conn states that fractures of the os calcis are serious and disabling injuries, in which the results continue to be "incredibly bad." Roentgenograms should be made in a manner well calculated to reveal both the perpendicular and lateral deflections. In fresh fractures, procrastination, attempts at manual deduction, and ineffectual immobilization should be abandoned in favor of the more radical and efficient skeletal traction procedures, tenotomy of the heel cord and, when indicated, subastragalar arthrodesis.

*Subastragalar Arthrodesis in Treatment of Old Fractures of the Calcaneus.*—Reich<sup>59</sup> reports four cases of old fractures of the os calcis which he treated by performing the operation of subastragalar arthrodesis. The results were satisfactory. He asserts that the pain in the old fractures is almost invariably due to a traumatic osteo-arthritis resulting from extension of the fracture into the subastragalar joint.

[ED. NOTE.—We agree that the only way by which the present poor results from fracture of the os calcis can be improved is by the more general adoption of radical procedures such as advised by Conn and Reich.]

58. Conn, H. R.: *Radiology* 6:228 (March) 1926.

59. Reich, R. S.: *Surg. Gynec. Obst.* 42:420 (March) 1926.

# THIRTY-FIRST REPORT OF PROGRESS IN ORTHOPEDIC SURGERY \*

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(Continued from page 164)

## RESEARCH

*Physiology of Synovial Fluid.*—Pemberton <sup>37</sup> and his group conclude from their experiments that diffusible substances pass easily from the blood to the synovial fluid, and that the gastro-intestinal tract must be regarded as being in surprisingly close communion with the joint fluids.

*Interstitial Growth in Growing Long Bones.*—Haas <sup>38</sup> has performed experiments in growth, using rabbits in which the measurements were controlled by being taken on roentgenograms at the time of operation and at the end of the period of observation. With a constant film target distance there is practically no chance for error, as is the case in making measurements at the time of operation. He concludes that interstitial proliferation of osseous tissue plays no part in the elongation of bone, either in the mature bone or in the young osteoid tissue bordering on the epiphyseal cartilage. Length of bone is entirely dependent on the purposeful multiplication of the cartilage cells of the epiphyseal plate.

*Bone and Blood Circulation.*—Mueller <sup>39</sup> has examined bones taken from old people with severe arteriosclerosis to determine the connection of the circulation with the nutrition of the bone tissue. Those lamellae which are near the vessels are intact, while those farther away are generally necrotic. Therefore, the lamellae in the marrow and in the cancellous bone are living, while in the compact bone only those lamellae are intact which are close to the haversian canals. In severe

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\* This Report of Progress is based on a review of 230 articles selected from 595 titles dealing with orthopedic surgery appearing in medical literature between March 13 and July 24, 1926. Only the articles that seem to represent progress have been selected for note and comment.

37. Cajori, F. A.; Crouter, G. Y., and Pemberton, R.: Arch. Int. Med. 37:92 (Jan. 15) 1926.

38. Haas, S. L.: Arch. Surg. 12:887 (April) 1926

39. Mueller, W.: Zentralbl. f. Chir. 54:1412 (May 29) 1926.

no endothelial lining (exception, Ollerenshaw's case). 3. They are filled with a mucoid substance. 4. There is no evidence of inflammatory reaction about them. 5. The cysts have in all cases been located in the midportion of the semilunar cartilage on the external border. 6. A definite history of injury was present in almost half of the cases. 7. The cysts reach their maximum size quickly and then remain stationary. 8. Most of the patients were in the second decade of life. 9. Spontaneous recovery is unknown and recurrences have taken place in which the entire cartilage was not removed. 10. Pain is present on complete extension and on acute flexion of the knee.

[ED. NOTE.—We have been impressed with the fact that cysts of the semilunar cartilage are not uncommon and that in the majority of the cases the diagnosis can be made readily from the clinical evidence.]

*Posterior Contusion of the Patella.*—Haglund<sup>63</sup> calls attention to a lesion that has been encountered frequently in his clinic, but which apparently is not generally recognized. He terms the condition posterior contusion of the patella and ascribes it to a severe trauma to the patella when the knee is flexed. The roentgenographic appearance is said to be characteristic. In the lateral view, there is a distinct cavity in the posterior surface of the patella, while the surrounding bone shows increased density similar to that of cortical bone. In early cases, atrophy and necrosis can be made out, the picture at times somewhat resembling tuberculosis. Haglund believes that the condition recently described by Freund under the name "chondropathia of the patella" is the same lesion. Contrary to Freund, Haglund does not consider operation necessary for cure in all cases, and says that many of them heal without any special treatment.

*Lesions of the Sacro-Iliac Joints.*—Painter<sup>64</sup> has made an exhaustive survey of all the evidence that has accumulated in respect to the anatomy, physiology and pathology of the sacro-iliac joints. From this study he feels that the conclusion is warranted that the sacro-iliac articulations are subject to the same lesions as all other joints and that the presence of a pathologic condition in the joint is manifested by the same signs and symptoms that are encountered elsewhere. He feels that the evidence is overwhelming that sciatica is a cardinal symptom of sacro-iliac lesions, and that it is due to a perineuritis brought about by the proximity of the radicals making up the sciatic nerve to whatever lesion is affecting the joint. He states that the accumulated experience shows that in the traumatic lesions of the sacro-iliac joints good results may ordinarily be obtained from mechanical and physiotherapeutic methods of treatment, and that this should cause those advocating operative measures

63. Haglund, P.: Zentralbl. f. Chir. 53:1757 (July 10) 1926.

64. Painter, C. F.: Boston M. & S. J. 194:613 (April 8) 1926.

splints the finger for eight days, and only at the end of this time does he begin gentle active motion. As a rule, about 75 per cent of the normal motion is recovered within four weeks after the operation.

Närvi<sup>43</sup> has made a study of tendon suture and tendon repair, using cats as experimental animals. His conclusions are: 1. After tendon suture the ends of the tendon are united by means of granulation tissue, which is formed by the connective tissue elements of the tendon. The ends remain passive and do not seem to form any new tissue. The connective tissue outside the tendon forms more of the granulation tissue between the ends than the peritenoneum and is therefore of more importance for the healing of the tendon wound. In the endothelium covered sheath of the tendon, the peritenoneum grows over the ends of the tendon, forming stumps that do not unite, but if sutures are passed through the cut surfaces granulation tissue is formed from the peritenoneum along and around the sutures. The author therefore recommends this type of tendon suturing. 2. The synovial fluid does not affect the regeneration of the tendon disadvantageously. The form and structure of the cicatrix of the tendon is consequently quite the same inside and outside the sheath of the tendon. 3. For restoration of function it is absolutely necessary to spare the sheath of the tendon in order to facilitate the gliding movements and to keep the tendon in the right position. 4. Only by exercises, without immobilization, is it possible to prevent adhesions of the tendon.

*Arthroplasty.*—In arthroplastic operations, Hass<sup>44</sup> recommends a different method of modeling the ends of the bones from that which is commonly used. He does not try to reconstruct the normal anatomic form, but rather to shape the bones from a functional point of view. The convex articular body—e. g., the lower end of the femur—is shaped like a wedge, while the concave body—e. g., the upper end of the tibia—is modeled into the form of a shallow cavity. The idea is by this means to minimize as much as possible broad contact of the bony surfaces and thus to prevent the formation of adhesions. He reports the results in five cases in which operations were performed by this method from one to two years previously, two in the elbow, two in the knee and one in the hip. The results in the elbows are excellent, full range of motion and function scarcely differing from normal. In the knees the range of active motion is excellent, although in one case the stability is somewhat impaired. In the hip there is active flexion of 90 degrees, abduction to 60 degrees and good extension.

[ED. NOTE.—We feel that these operations might properly be called reconstructions or resections rather than arthroplasties, as the term is commonly understood.]

43. Närvi, E. J.: *Acta Chir. Scandinav.* 60:1 (March 10) 1926.

44. Hass, J.: *Zentralbl. f. Chir.* 52:270 (Nov. 28) 1925.



the main factor is a necrosis, whereas the inflammation and dissection are secondary characteristics. It has often been questioned whether the process is of traumatic or nontraumatic origin. Koenig agrees with his father that both causes may be found. He had made a careful study of twenty-seven cases at different stages. The histologic examination showed necrosis of the bone and of the fibrous tissue within the marrow. He supports the views of Axhausen in respect to embolism as an etiologic factor in certain cases, and states that the production of osteochondritis by this means has been clearly demonstrated by experiments.

*Kienbock's Disease.*—Fontaine<sup>68</sup> regards Kienbock's disease of the carpal semilunar bone as primarily a process of atrophy following trauma. He reports the case of a young man who injured the semilunar bone by catching a brick which had been thrown to him. Atrophy and softening of the bone followed, but all disturbances ceased after the removal of the semilunar bone. He calls attention to the fact that Müller obtained a good result in a similar case by curetting the interior of the bone, preserving the outer cortical shell.

*Osteochondritis Metatarsophalangeal, Infraction of the Second Metatarsal Bone, March Foot.*—The lack of knowledge concerning a condition of the head of the metatarsal commonly designated by the name of Koehler is well shown by the presence of three articles in the current literature, each describing a more or less similar condition under a different name. Under the title "Osteochondritis Deformans Juvenilis, Metatarsophalangeal," Schaller and Nadaud<sup>69</sup> describe the roentgenologic features in a case that they have followed. There is a shortening of the head of the bone, with flattening and broadening, condensation of the spongy bone, widening of the intra-articular space and preservation of the normal appearance of the opposing articular surface. A plaster splint was applied in their case, but notwithstanding this, the lesion progressed markedly during the ensuing five months.

Freiberg<sup>70</sup> employs the term metatarsal infraction, and reports a case in which the first roentgenogram did not show any bony abnormality, but a second roentgenogram taken eight months later showed the typical changes mentioned by Koehler. He acknowledges that simple trauma is not a satisfactory explanation of the clinical and roentgenologic phenomena that have been described in this condition.

March foot is the term Jansen<sup>71</sup> applies to the well-known edematous swelling of the metatarsal region of the foot which is seen in persons who are made to walk beyond their strength. Jansen considers this the

68. Fontaine, R.: *Rev. de Chir.* 63:769, 1926.

69. Schaller and Nadaud: *J. de radiol. et d'électrol.* 10:123 (March) 1926.

70. Freiberg, Albert: *J. Bone & Joint Surg.* 8:257 (April) 1926.

71. Jansen, Murk: *J. Bone & Joint Surg.* 8:262 (April) 1926.

The advantages of the method are accuracy, elimination of the risk of displacing fragments and doing away with the necessity of applying a plaster cast following the operation.

*Operative Treatment of Chronic Hydrops of the Knee.*—Muchin<sup>47</sup> has tried a new procedure for the relief of chronic hydrops of the knee, and in four cases has obtained good results. The idea is to improve the drainage and absorption from such knees by excision of a piece of the capsule. The edges of the capsular defect are sewn to the subcutaneous tissues, and into the defect a small pedunculated flap of muscle and fascia is turned. The patients on whom operations were performed have been observed for more than a year, and within this period there has been no recurrence of the swelling.

[ED. NOTE.—We judge that this procedure is based on the same idea that underlies the Kondoleon operation for elephantiasis, namely, to connect the superficial lymphatics with the part that it is desired to drain. If an essential part of the plan is the persistence of the capsular defect, then the operation would appear to be illusory, since we know that such a defect is quickly closed and the synovial lining rapidly reconstituted.]

*Late Results of Resections of the Knee Performed by Ollier.*—Berard and Santy<sup>48</sup> have investigated the late results in some of Ollier's operations of resection of the knee for tuberculosis. Twenty-five cases were selected from his records at the time of his greatest surgical activity, about thirty years ago. Of these twenty-five patients, sixteen, or 64 per cent, were found to be in good health, five did not respond, and four had died, but only one of a tuberculous disease. Of the sixteen patients that were found, eleven have been examined. All have been permanently cured of their knee joint disease. No complications have been noted. One patient, who at the time of operation had lupus of the ear and signs of a pulmonary lesion, has had pleurisy. None of the other patients ever showed any new tuberculous symptoms. In all the cases but one, ankylosis, the aim of the operation, was achieved. In the one case of failure, new tuberculous lesions were detected and a second operation was performed five years after the first, with a successful result. The knees were ankylosed with about 10 or 12 degrees of flexion. The functional results were excellent, and although the patients were mostly farmers and laborers, all were capable of the same efforts as normal people. There was no difficulty in mounting stairs, only slight awkwardness in descending. The amount of shortening varied from 4

47. Muchin, M. W.: Taschilent Turkeston, abstr. in *Zentralbl. f. Chir.* 53:2037 (Aug. 7) 1926.

48. Berard, L., and Santy, P.: *Arch. franco-belges de chir.* 28:963 (Nov.) 1925.

## BOOK REVIEWS

ORTHOPEDIC SURGERY. By W. B. COCHRANE. Edinburgh: E. & S. Livingstone, 1926.

Much is heard of preventive medicine, but little of preventive surgery, and yet in orthopedic surgery the ounce of prevention is often worth the ton of cure. Cochrane founds his work on orthopedic surgery on preventive measures of physical education, acknowledging his debt to his American teacher, Goldthwait. He recalls the work of Nicholas Andry, who defended his thesis "Orthopaedia" before the Faculty of Medicine in Paris, of which he was the dean. Having laid his foundations of body mechanics, Cochrane proceeds to outline under anatomic groupings the various diseases and lesions of the locomotary apparatus which come within the field of orthopedic surgery. The book is designed to give medical students an idea of the scope of this branch of surgery, and to suggest to them the principles of diagnosis and treatment. It fulfils its purpose admirably, and will be found even more valuable for general practitioners than for undergraduates. It is an original and sound presentation which should be widely read.

THE INFLAMMATION AND TOXIC DISEASES OF BONE. A TEXTBOOK FOR SENIOR STUDENTS. By R. LAWFORD KNAGGS, M.C., F.R.C.S., Consulting Surgeon to the Leeds General Infirmary; formerly Professor of Surgery in the University of Leeds. New York: William Wood & Co., 1926.

This interesting book, written by a surgeon of wide experience, who has devoted the years since his retirement from active surgical duties to research, is a valuable contribution to the subject of inflammatory and toxic diseases of the bone. As he says, it is a textbook for senior students, and the subjects that receive special attention are osteomyelitis, tuberculosis, syphilis, the arthropathies, yaws, arthritis deformans, rickets, scurvy, osteomalacia, Pott's disease, leontiasis ossea and osteogenesis imperfecta. There is a wealth of illustration of both the macroscopic and the microscopic appearance of these diseases, and the etiology, pathogenesis and morphology are extremely well covered, while only the general principles of treatment are outlined. He believes that most of the conditions that he describes have a background of infection, and that their lesions are probably caused by toxins elaborated in the body from such foci. The book, which consists of 400 pages, is a valuable contribution to the subject of inflammatory and toxic diseases of the bone.

BONE SARCOMA. By E. A. CODMAN. New York: Paul B. Hoeber, 1926.

This book describes in concise terms the uniform classification of tumors of the bone recognized by the American College of Surgeons. It will lead to a much clearer conception of tumors of the bone and will enable surgeons everywhere to compare results and observations in a common language. Fortunately, it is to be widely distributed by the American College of Surgeons, and will undoubtedly be closely followed.

the former distal to the point of suture. The primary results have been encouraging, although as yet sufficient time has not elapsed to know the final outcome.

In another article, the same author<sup>51</sup> deals with the treatment of pes cavus along similar lines. He points out that in cases of isolated paralysis of the peroneus longus muscle there results a flat, pronated foot. Consequently, in cases of hollow foot in young persons he cuts the long peroneal tendon and sutures this muscle to the peroneus brevis. In all cases in which this procedure has been employed there has been noted a progressive correction of the deformity.

#### FRACTURES

*Muscle and Nerve Injuries Associated with Fractures.*—Lewis,<sup>52</sup> speaking of nerve and muscle injuries associated with fractures, states that these lesions are relatively rare, but that when present they so prolong the disability that early recognition and intelligent therapy are demanded. In 80 per cent of the nerve injuries, the humerus is the bone that is fractured, the common site of the fracture being in the lower third of the bone (60 per cent). Of the peripheral nerves involved, the musculospiral accounts for 60 per cent, and the ulnar nerve for about 25 per cent. Many of the latter, however, are late paralyses. Ischemic myositis (Volkmann's contracture) is one of the most disabling lesions associated with fractures. It is observed most frequently after supracondylar fractures and fractures of the lower end of the humerus. It is caused by venous congestion. About 8 per cent of the cases of ischemic palsy occur without a cast or constricting dressing having been applied. The importance of the subfascial hematoma in the production of ischemic palsy has not been fully appreciated. A fracture should not be considered merely as a skeletal injury, but a careful examination should also be made for associated injuries of nerves, muscles and blood vessels.

[ED. NOTE.—Some of us have encountered cases in which ischemic myositis was present when the patient was first seen and before any dressing had been applied for the fracture. Contrary to the experimental evidence which is in favor of venous congestion as the causative factor, the finding in these cases was absent radial pulsation, pallor and coldness of the hand, together with inability to move the fingers. The first two developed typical ischemic contractures. In the third case, multiple incisions were made at the elbow, and part of the subfascial hematoma evacuated, with the result that the ischemia disappeared and the hand remained normal. This procedure would seem worthy of trial in any similar case.]

51. Schulze-Gocht: Arch. f. Orthop. d. Unfallchir. 24:19, 1926.

52. Lewis, Dean: Proc. M. Soc. State of N. Y., March 30, 1926, reported in J. A. M. A. 86:1380 (May 1) 1926.

definition that requires demonstration of an actually plugged capillary does not seem useful to us for reasons that will appear later. If there is microscopic (as opposed to ultramicroscopic) free fat in the blood stream, a sufficient agglomeration of particles may occur anywhere and at any time to plug a capillary.

The general problem of fat embolism, then, must be divided into two main divisions. The first of these concerns itself solely with the sources of free neutral fat in the blood stream and the mechanisms of its appearance there. The second deals with the results of this entrance of fat into the blood stream as expressed by pathologic and clinical changes. It must therefore take into consideration quantity, distribution and composition of the fat introduced.

#### PART I. ETIOLOGY OF FAT EMBOLISM

There is no doubt that depot fat, particularly that of the marrow, will enter the blood stream following mechanical disturbance. Hundreds of cases demonstrating this fact are on record, as may be seen by reference to the reviews of the subject already mentioned. The types of mechanical injury include fracture, operations on soft parts and on bone, and severe concussion of the body. Traumatic etiology can be readily demonstrated experimentally.<sup>4</sup> Mechanical disturbance of marrow fat, experimental fracture, jarring of bones, experimental bone transplants, in fact, all procedures leading to any appreciable damage to fat depots are regularly accompanied by the appearance of intravascular fat in varying quantities and by resulting degrees of capillary occlusion. To confirm these findings we have successfully repeated certain of these experiments (figs. 1, 2 and 3). The lung embolism seen in figure 1 appeared in the brief interval between the occurrence of multiple fractures of the skull and death in a dog. Figures 2 and 3 show the embolism present in the lungs of rabbits six hours after destruction of the bone marrow of a single femur under ether anesthesia. The degree of embolism in these instances is to be kept in mind for comparison with later experimental results.

The ease and logic of this explanation for certain examples of fat embolism have misled those interested in the problem. Time and again in the literature of the subject the statement is made that trauma is the only possible cause of fat embolism. Examples of these statements are the following: "In order to permit the entrance of fat into the circulation in amounts even to approach the amount of free fat in the blood

4. Busch: *Arch. f. path. Anat.* **35**:321, 1866. Ribbert: *Cor. Bl. f. schweiz. Aerzte* **24**:457, 1894. Fritzsche: *Deutsche Ztschr. f. Chir.* **107**:456, 1910. Bergemann: *Berl. klin. Wchnschr.* **47**:1112, 1910. Bissell, W. W.: *Surg. Gynec. Obst.* **25**:8 (July) 1917. Caldwell, G. T., and Huber, H. L.: *Surg. Gynec. Obst.* **25**:650 (Dec.) 1917.

time it has been used in all types of cases. The nerve block method, either of the brachial plexus for the upper extremity or by spinal injection for the lower extremity, has also been used in exceptional cases. The local infiltration method is easier and has proved a practical procedure. It has been used satisfactorily in fractures of the shaft of the femur, humerus and tibia. The one contraindication is a compound fracture. The muscular relaxation which is obtained is not as great as with general anesthesia.

[ED. NOTE.—Some of us have employed the nerve block method of local anesthesia, although we have had no experience with the local infiltration method. For the reduction of Colles' fracture and other types of forearm and elbow fracture in persons who are poor anesthetic risks, it is the method of choice.]

*Traction on Sternum in Treatment of Multiple Fractures of the Ribs.*—Jones and Richardson<sup>55</sup> report the case of a man with multiple fractures of the ribs, from the second to the eighth on one side, with great shock and marked difficulty in breathing. They made an incision on either side of the sternum, through which the jaws of a bullet forceps were introduced to grasp the sternum. They were locked in this position and by means of a cord fastened to the handles, leading to an overhead pulley and counterpoise weight, continuous traction was exerted on the sternum and depressed portion of the chest. The dyspnea was greatly relieved. The danger in the procedure lies in the proximity of the pleura.

*Fracture of Semilunar Bone from Indirect Violence.*—Palmer<sup>56</sup> reports an unusual case of fracture of the semilunar bone from indirect violence. The fracture was visible only in roentgenograms taken with the wrist in the position of extreme flexion. These showed the anterior horn separated from the body of the bone. The injury was produced by lifting a 100 pound bag of cement. The symptoms were pain and weakness.

*Ununited Fracture of the Hip.*—Henderson,<sup>57</sup> writing on ununited fracture of the hip, asserts that the autogenous bone graft, the aim of which is to restore as nearly as possible the normal anatomy, is the operation of choice. He asserts that the fact that success was attained in 76 per cent of the twenty-one cases in which he has performed this operation indicated that this procedure compares favorably with bone grafting operations for nonunion in other bones. In three cases the same results were achieved by using the beef bone screws, but these

55. Jones, T. B., and Richardson, E. P.: Surg. Gynec. Obst. 42:283 (Feb.) 1926.

56. Palmer, J. H.: Canad. M. A. J. 16:170 (Feb.) 1926.

57. Henderson, M. S.: Ann. Surg. 83:696 (May) 1926.

of postinfluenzal pneumonia. Gröndahl<sup>10</sup> reports fat embolism in two cases of eclampsia, four cases of diabetes, and two cases of phosphorus poisoning; Winkler<sup>11</sup> in two cases of acidosis, and Winogradow<sup>12</sup> as occurring regularly in potassium chlorate poisoning. In addition to these repeated findings there have been authentic reports of fat embolism having occurred, without history of trauma, in one or more cases of each of the following conditions: carbon monoxide poisoning,<sup>8</sup> profound sepsis,<sup>10</sup> chronic alcoholism,<sup>10</sup> chloroform narcosis,<sup>11</sup> diabetic retinitis,<sup>13</sup> phlegmonous gastritis,<sup>10</sup> acute pancreatitis,<sup>8</sup> chronic tuberculosis,<sup>8</sup> menstrual suppression, hepatitis, splenitis, carcinomatosis and sarcomatosis.<sup>1</sup> (The last five conditions are cited from the literature by Warthin.)

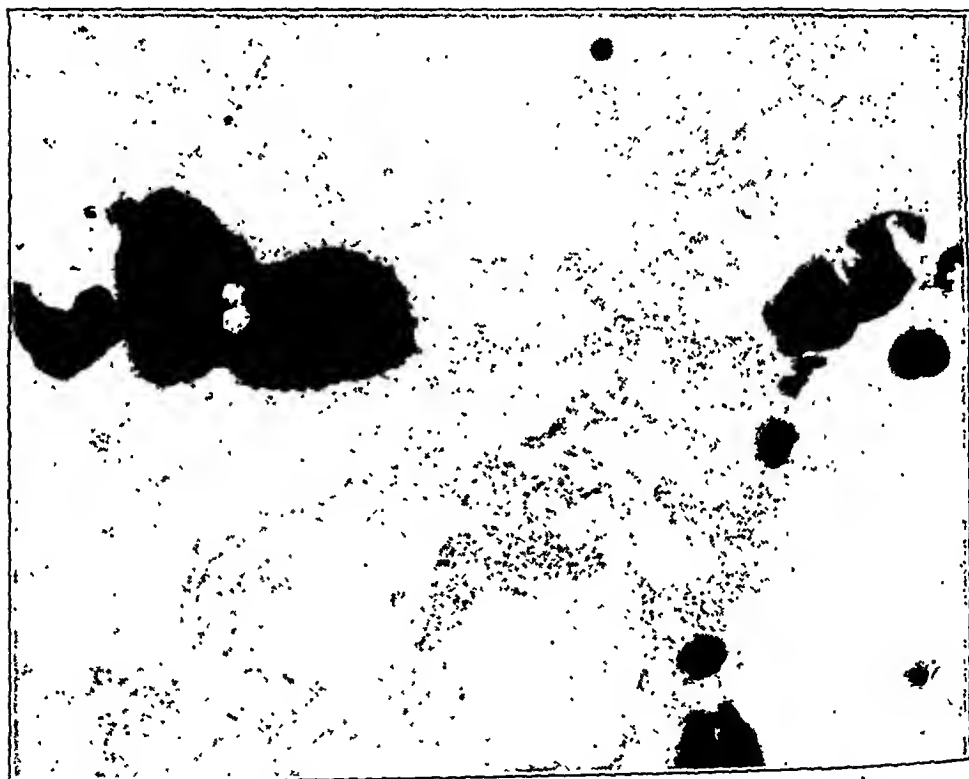


Fig. 2.—Experimental traumatic fat embolism: lung section (high power, sudan III) from rabbit killed six hours after destruction of bone marrow of a single femur.

For the sake of convenience we can group most of these varying conditions under four main heads: (1) metabolic disturbances (diabetes, cardiovascular-renal syndrome); (2) poisonings; (3) toxemias from acute infections, and (4) toxemias from tissue destruction (burns).

10. Gröndahl (footnote 8).

11. Winkler: *Ztschr. f. orthop. Chir.* 45:616, 1924.

12. Winogradow: *Virchows Arch. f. path. Anat.* 190:92, 1907.

13. Bantin, C. F.: *Diabetic Lipemia Retinalis and Fat Embolism*, J. A. M. A. 86:546 (Feb. 20) 1926.

## AMPUTATIONS

*Artificial Limbs: Their Relation to the Different Types of Amputation Stumps.*—LeMesurier,<sup>60</sup> writing on amputation stumps viewed from the standpoint of prosthesis, points out that in spite of all that has been published on this subject since the war, few surgeons appear to have enough knowledge of artificial limbs to do the best thing for their patients. In civil practice, one still sees stumps that have been amputated at unsuitable levels, improperly fashioned flaps and joint contractures. There has been no general adoption of the temporary shrinkage appliances which result in such great saving of time and money and there appears to be a surprising lack of knowledge of even the fundamental principles of prosthesis. He is strongly of the opinion that the end weight bearing stumps, such as the Syme and the Stokes-Gritti, give the best results, and raises the question whether the results obtained with the latter are not even better than those with amputation of the leg below the knee. His description of the standard types of appliance to be used with the various kinds of amputation is clear, as also the exposition of the principles of their use.

*Kineplastic Amputation: Arm-Bimotor and Prosthesis.*—Bosch Arana<sup>61</sup> reports the results of his experience with the kineplastic amputation in the upper extremity, employing a bimotor made from the biceps and triceps muscles. Three factors enter into the success of the procedure: the surgical factor, the orthopedic factor and the human factor of the individual patient. The latter is the key to complete success. Discussing results, the author states that all of his patients can grasp any object of average weight, can lift it to the mouth or either side of the head and can bend the arm or extend it. They can perform all the motions of pronation and supination necessary to hold objects or to take articles and carry them to the mouth and raise the hand in complete abduction so as to form a right angle with the body.

## MISCELLANEOUS

*Cysts of Semilunar Cartilages.*—From a study of three cases of cysts of the semilunar cartilages and from a review of cases previously reported in the literature, Allison and O'Connor<sup>62</sup> conclude that these cysts represent the end-result of a degenerative process caused by an interference with the blood supply to a portion of the cartilage, the exciting cause being a nonlacerating injury. The salient features common to all the cases are: 1. The cysts are multilocular. 2. They have

60. LeMesurier, A. B.: J. Bone & Joint Surg. 8:292 (April) 1926.

61. Bosch Arana, G.: Surg. Gynec. Obst. 42:416 (March) 1926.

62. Allison, N., and O'Connor, D. S.: Surg. Gynec. Obst. 42:259 (Feb.) 1926.



*Trauma, therefore, is not the cause of all fat embolism, nor as a corollary is the free fat found in cases associated with trauma necessarily all due to the trauma itself.*

Before proceeding to experimental results that may cast some light on the questions (1) from what other sources than depot fat and (2) by what other mechanism than trauma does neutral fat appear in the blood, it will be well here to suggest a thought that will color the succeeding argument. If such other source can be proved, and such other mechanism can be demonstrated, then it becomes possible that any case of traumatic fat embolism except those fatal within a few minutes may possess a double etiology. The importance of this conception becomes clear in reviewing Porter's<sup>14</sup> work on fat embolism and shock. He believed that the shock state could be initiated by fat embolism, and he observed fat embolism in patients dead of shock. Now shock of a certain type may be regarded as an intoxication with products of tissue destruction. If fat embolism can occur from chemical changes in the blood (as the review above suggests) then the embolism observed may be the result of shock rather than its cause.

We present experimental evidence suggesting that (1) there is an obvious source of fat in fat embolism, other than depot fat—one that has been dismissed by numerous authors with mention only—namely, the ultramicroscopic emulsion of fat in the normal blood plasma; (2) the mechanism by which this physiologic emulsion is coarsened so that droplets are found of a size capable of producing embolism is that already suggested, namely, physical or chemical changes in the blood.

The physiologic occurrence of fat in the blood plasma varies greatly with the state of nutrition. It occurs in ultramicroscopic particles seen in the dark field as refractile bodies that exhibit active Brownian movement.<sup>15</sup> The number of these in the organism starved for twenty-four hours is very small; under such circumstances it is sometimes almost impossible to find one in many fields. Following a rich fat meal, however, they crowd every field so intensely as to make a perceptible increase in the amount of light that is refracted into the observer's eye. Quantitative fat determinations show physiologic variations in blood fat content in man from 0.2 to 2 per cent and in the dog from 0.1 to 2 per cent.<sup>16</sup> In man under pathologic conditions it may rise as high as 26 per cent.<sup>13</sup> This fine emulsion is the result of resynthesization of the fed fat that has been hydrolyzed in the intestine. It is presumed to be stabilized by soaps formed from fatty acids also originating from the fed fat in the process of hydrolysis.

14. Porter, W. T.: Boston M. & S. J. 176:248 (Feb. 15) 1917; *ibid.* 177:326 (Sept. 6) 1917; Am. J. Physiol. 71:277 (Jan.) 1925.

15. Neumann: Centralbl. f. Physiol. 21:102, 1907. Gage, S. H., and Fish, P. A.: Am. J. Anat. 34:1 (Sept.) 1924.

16. Leathes and Raper: The Fats, London, 1925, p. 144.

other than manipulative to hesitate. It is his belief that open operative interference in this group of cases is practically never indicated, and should never be undertaken until after prolonged spica treatment has been tried.

[ED. NOTE.—Painter's study and critical analysis of the evidence in favor of sacro-iliac lesions as a cause of backache is a valuable contribution and deserves to be read. It is fair to say that we are not in agreement concerning the relationship of sciatic pain to sacro-iliac lesions. While it is the part of wisdom to warn against too hasty operative intervention now that the technic of arthrodising operations has been perfected, we recognize that this procedure has a definite place in the treatment of certain of these cases.]

*Periarthritis of the Shoulders.*—Schulkof<sup>65</sup> has made a study of the periarticular spaces of the shoulder by means of the injection of iodized oil, 40 per cent, and various dyes. He finds in practically all cases a definite connection between the two large bursae, the subdeltoid and the subaxillary. In cases of periarthritis of the shoulder, he has injected from 30 to 50 cc. of 0.125 per cent solution of procaine into the subdeltoid bursa and found that by this means he was able to relieve the pain and to mobilize the shoulder.

*Scapular Myalgia.*—Fuerstenberg<sup>66</sup> believes that scapular myalgia constitutes a distinct entity. The condition begins rather suddenly with pain in the scapular region, which rapidly increases in severity. It is made worse by movement and relieved by rest. The arm seems powerless and is held rigidly to the side. The muscles of the scapula are tense and hard, showing distinct hypertonicity. There is marked tenderness on pressure and the skin is hyperesthetic. If the condition lasts, the muscles atrophy. The shoulder joint itself shows no limitation of motion. The roentgenograms are negative. He believes the condition may originate in infection from remote foci, from exposure to cold, from mechanical strain, but especially from metabolic disturbances.

[ED. NOTE.—Before making a diagnosis of scapular myalgia one must be careful among other possibilities to eliminate lesions of the spine with referred pain to the scapular region. Careful methods of examination have reduced the number of cases of myalgia to the point that this condition is now rarely diagnosed.]

*Osteochondritis Dissecans.*—Koenig<sup>67</sup> in a discussion before a German surgical congress on osteochondritis dissecans, stated that the name osteochondritis dissecans is not sufficiently descriptive of the process, as

65. Schulkof: *Zentralbl. f. Chir.* 53:1364 (May 29) 1926.

66. Fuerstenberg: *München. med. Wchnschr.* 73:734 (April 30) 1926.

67. Koenig: *Zentralbl. f. Chir.* 53:1411 (May 29) 1926.

sions (Premier mill). It is stable over months. Under the microscope it shows a much smaller average size of droplets. There are even ultra-microscopic dancing refractile bodies such as have been described in the blood plasma.

C. This is the physiologic emulsion of blood serum described as occurring after a fat meal. Dogs were fed a pint of cream and bled at the end of one and one-half to two hours. The blood was immediately defibrinated, the corpuscles removed by centrifugalization, and the creamy serum used. The gross appearance of the serum was the only guide to the degree of lipemia.

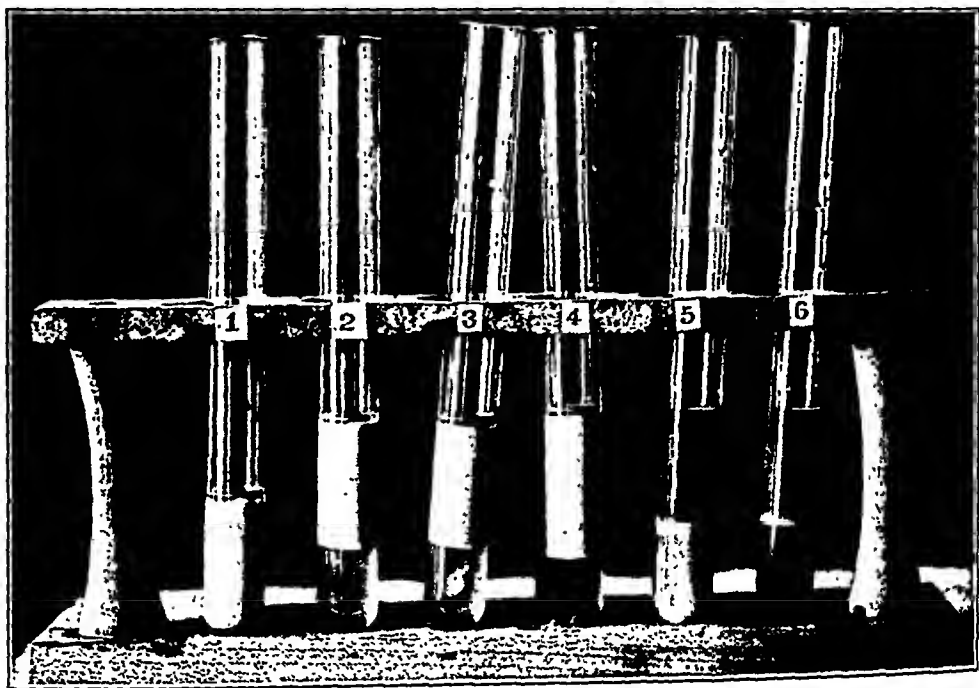


Fig. 4 (experiment 9).—Emulsion A, 5 cc., treated with reagents as follows: tube 1, none; tube 2, 3 cc. of tap water; tube 3, 3 cc. of 0.7 per cent sodium chloride solution; tube 4, 3 cc. of saline extract of fresh muscle; tube 5, 3 cc. of saline extract of necrotic muscle; tube 6, 3 cc. of same extract as tube 5, rendered alkaline to litmus. Complete breaking down of emulsion by necrotic muscle extract should be noted; photographed at ninety hours.

Differences in the behavior of these three emulsions to various agents occurred, as will be seen hereafter.

Each series of breakdown experiments was controlled by tubes containing the untreated emulsion, and dilutions of the emulsion with tap water and physiologic sodium chloride solution. In no instance in which the emulsion was properly made did more than a minimal freeing of the oil occur in these controls. Only satisfactorily controlled emulsions were recorded.

result of overfatigue in a weak foot, with resulting spasm of the inter-ossei muscles, circulatory stasis, thickening of the periosteum and brittleness of the bony tissue, eventually leading to fracture.

*Roentgenologic Observations in Hemophiliac Joints.*—Doub and Davidson <sup>72</sup> classify the roentgenologic observations in hemophiliac joints in two groups: the early cases without destructive changes and the advanced cases with destructive changes. In the first group, there is simple effusion of blood, which may or may not show calcification. There is thickening of the joint capsule and lipping similar to that of hypertrophic arthritis. In the second group, there is organized blood clot in the synovial cavity, punched-out areas of bone destruction in the epiphyses and points of cartilaginous destruction in the articular surfaces.

*Lateral Roentgenography of the Hip Joint.*—Béclère and Porcher <sup>73</sup> have made a study of various possible methods of obtaining lateral roentgenograms of the hip joints. The positions used were as follows: 1. The patient lies supine, the unaffected hip being flexed 90 degrees. The rays are directed upward from below the ischial tuberosity on the opposite side, passing through the adductor muscles of the affected hip. The plate is placed in close apposition to the trochanter, and the leg is in complete extension, the patella facing upward. 2. The patient lies supine with the legs fully extended. The rays enter on the side of the hip to be examined above the trochanter, and the plate is placed against the adductor muscles, perpendicular to the table. 3. The patient lies midway between the lateral and the prone positions. The plate is placed anterior to the trochanter, and the rays are directed laterally and anteriorly through the buttock. 4. The patient lies on the side, but rolled a little backward so that the rays may enter just above the pubes, the plate being placed beneath the trochanter. 5. The patient lies supine. The rays enter above the ilium of the opposite side and pass through the body to reach the hip, the plate being placed against the trochanter and perpendicular to the table. 6. The patient lies prone at the edge of the table, the affected hip being slightly flexed with the leg extending down to the floor. The rays enter posteriorly and above the trochanter, the plate being placed anterior to the hip. 7. The patient lies supine, with the hip flexed to 90 degrees, and in a position of forced abduction. The rays are directed toward the hip from in front near the median line, the plate being placed behind. The authors state that the clearest outline of the acetabulum is obtained in the first, third, fifth and seventh positions.

72. Doub, H. P., and Davidson, E. C.: *Radiology* 6:217 (March) 1926.

73. Béclère, H., and Porcher, P.: *J. de radiol. et d'électrol.* 10:97 (March) 1926.

*Soap Precipitants.*—Calcium lactate, magnesium sulphate, manganese chloride, cobalt nitrate and all soluble salts of the heavy metals will displace the potassium in the emulsifying soap and precipitate an insoluble soap. There is rapid clearing of the oil in a solid layer on the surface.

*Acids and Alkalis.*—On the basis of only a few observations, it is probable that marked variations in acidity in either direction will free the fat in this emulsion. A volume of tenth normal hydrochloric acid or sodium hydroxide added to an equal volume of emulsion is moderately effective.

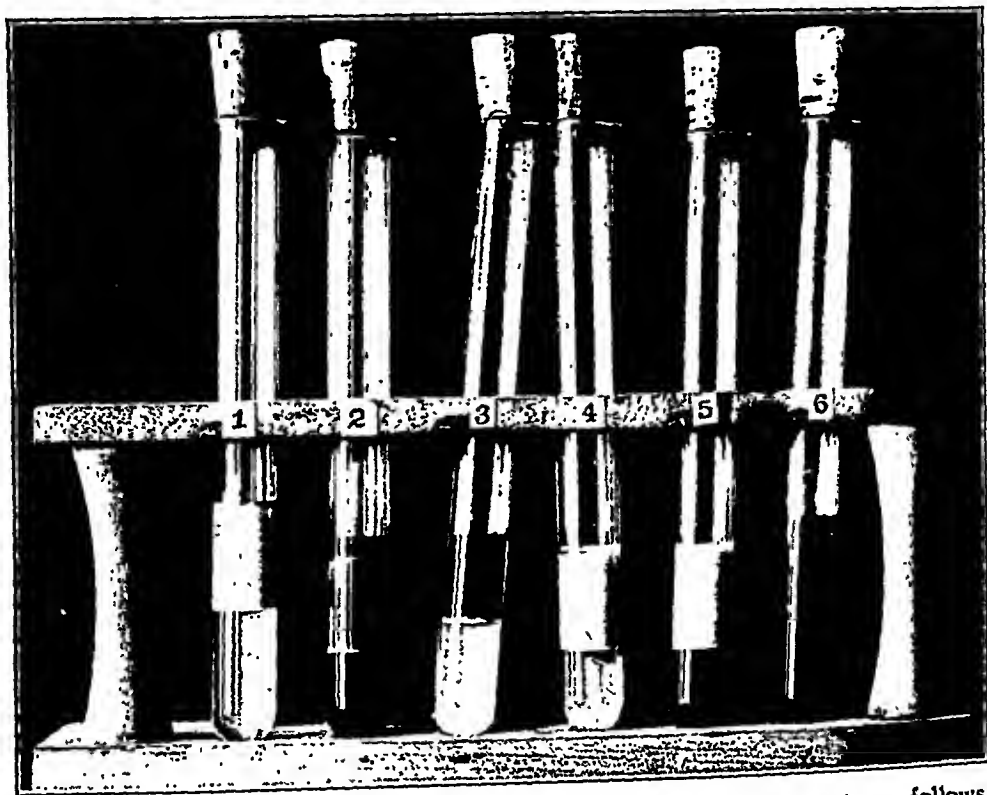


Fig. 6 (experiment 19).—Emulsion A, 5 cc., treated with reagents as follows: tube 1, 5 cc. of tap water; tube 2, 3 cc. of 1 per cent hemoglobin solution; tube 3, 3 cc. of 0.1 per cent histamine solution; tube 4, 3 cc. of 1 per cent sodium glycocholate solution; tube 5, 3 cc. of 1 per cent sodium taurocholate solution; tube 6, 3 cc. of fresh dog bile. Tube 3, treated with histamine, shows complete breakdown of emulsion, which occurred in a few seconds; photographed at forty-eight hours.

*Products of Protein Decomposition.*—Necrotic Muscle: The extract in physiologic sodium chloride solution of autolyzed muscle could, of course, not be calibrated. The muscle was autolyzed in vivo by aseptic isolation or in vitro, and was ground in a mortar with the salt solution. The mixture was filtered through gauze, forming a foul, brown, turbid liquid. The effect of this extract was uniformly prompt and positive. One failure was recorded. The reaction of the extract was rendered alkaline to litmus and methyl red with sodium hydroxide without alteration of its property of breaking the emulsion.

## FAT EMBOLISM

INCLUDING EXPERIMENTAL PRODUCTION WITHOUT TRAUMA \*

EDWIN P. LEHMAN, M.D.

AND

ROBERT M. MOORE, M.D.

ST. LOUIS

Since the discovery of free neutral fat in the blood vessels following injury, the subject of fat embolism has been widely investigated clinically and experimentally. As may so easily happen when an apparently direct and unequivocal cause-effect relationship is presented, the search for other causes has been overlooked; and this, in spite of the fact that the more familiar we become with fat embolism, the less unequivocal the commonly accepted etiology appears. This article is the record of an attack on this unsettled problem from a new direction.

A detailed review of the literature of fat embolism need not be given here. It has been thoroughly covered in English by Warthin (1913<sup>1</sup>) and in German by Landois (1923<sup>2</sup>), Paul and Windholz (1925<sup>3</sup>) and others.

We need only summarize those facts on which complete agreement exists among most authors, and in somewhat more detail discuss those observations that cast doubt on the sufficiency for all cases of the ordinary etiologic explanation.

In the first place, it is essential to make clear what we mean by fat embolism. The normal blood, even in digestive lipemia, contains no free neutral fat in droplets large enough to take the fat stains. Following injury to bone marrow and in certain other conditions to be emphasized later, free neutral fat can under the microscope be demonstrated in the blood stream by staining methods. This is the essence of the definition. The occurrence of symptoms or of death from the presence of this free neutral fat then becomes a question of quantity and distribution. A

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1. Warthin: *Internat. Clin.* 4:171, 1913.

2. Landois: *Ergebn. d. Chir. u. Orthop.* 16:99, 1923.

3. Paul, F., and Windholz, F.: *Mitt. a. d. Grenzgeb. d. Med. u. Chir.* 35: 14, 1925.

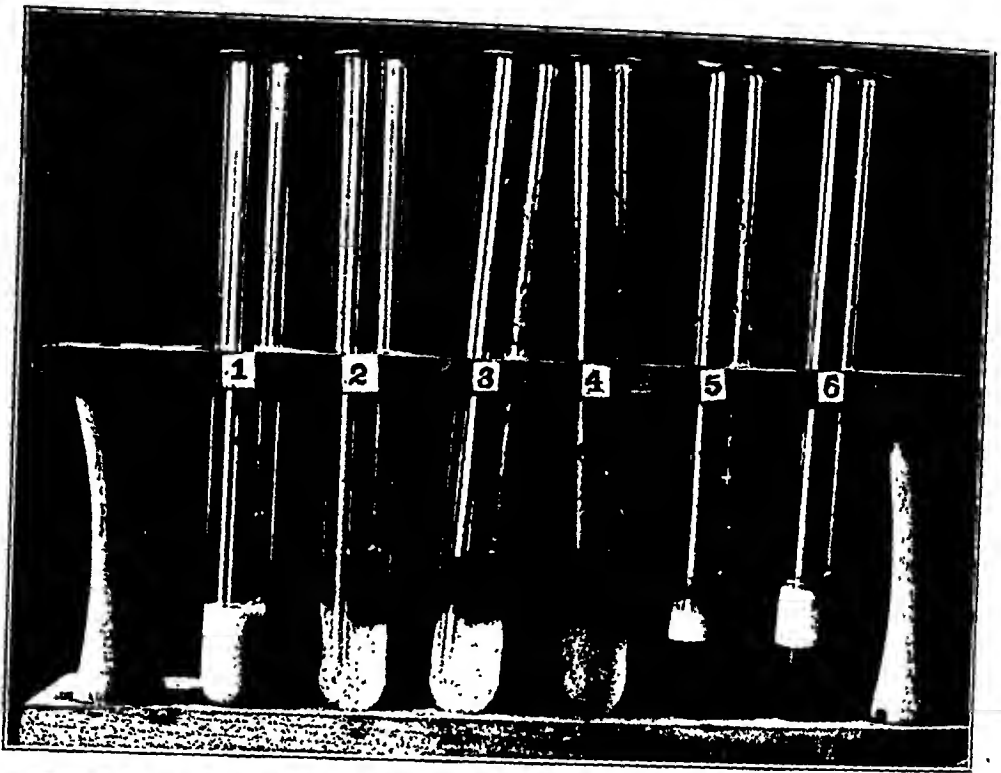


Fig. 8 (experiment 35).—Emulsion A, 5 cc., treated with reagents as follows: tube 1, none; tube 2, 3 cc. 1 per cent calcium lactate; tube 3, 3 cc. 0.2 per cent histamine; tube 4, 3 cc. 1 per cent peptone; tube 5, 3 cc. 0.5 per cent hemoglobin; tube 6, 3 cc. 1 per cent saponin. Calcium lactate, histamine and peptone show complete breakdown, hemoglobin and saponin partial breakdown; photographed at forty-eight hours.

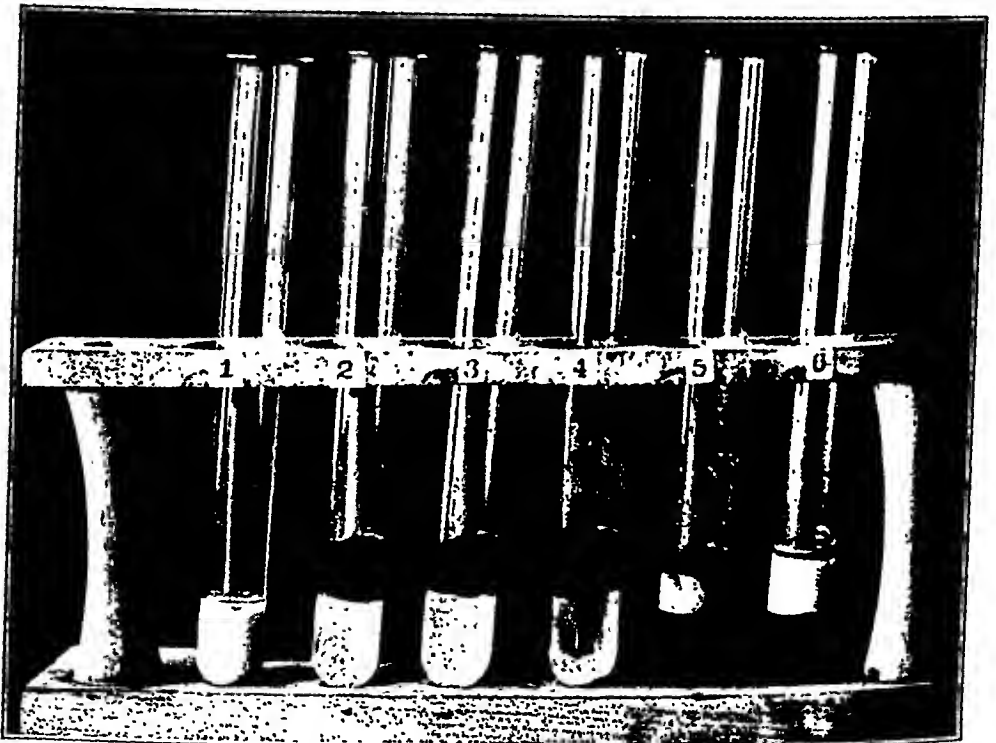


Fig. 9.—Same tubes as shown in figure 8 photographed at nine days to show permanence of the reaction.

stream in pulmonary fat embolism, there must first be injury to the fatty tissue and, second, a break in the continuity of the blood stream."<sup>5</sup> "Fat embolism is an acute circulatory disturbance caused by trauma."<sup>6</sup> "The cause is always trauma."<sup>6</sup> "Fat in the minute particles of emulsification or saponification plays little if any important rôle in the production of embolism."<sup>7</sup> Evidence is not produced to support these statements.

There is no question of the occurrence of traumatic fat embolism, but there is equally no question that trauma is not the only cause of fat embolism. The following observations recorded in the literature of the

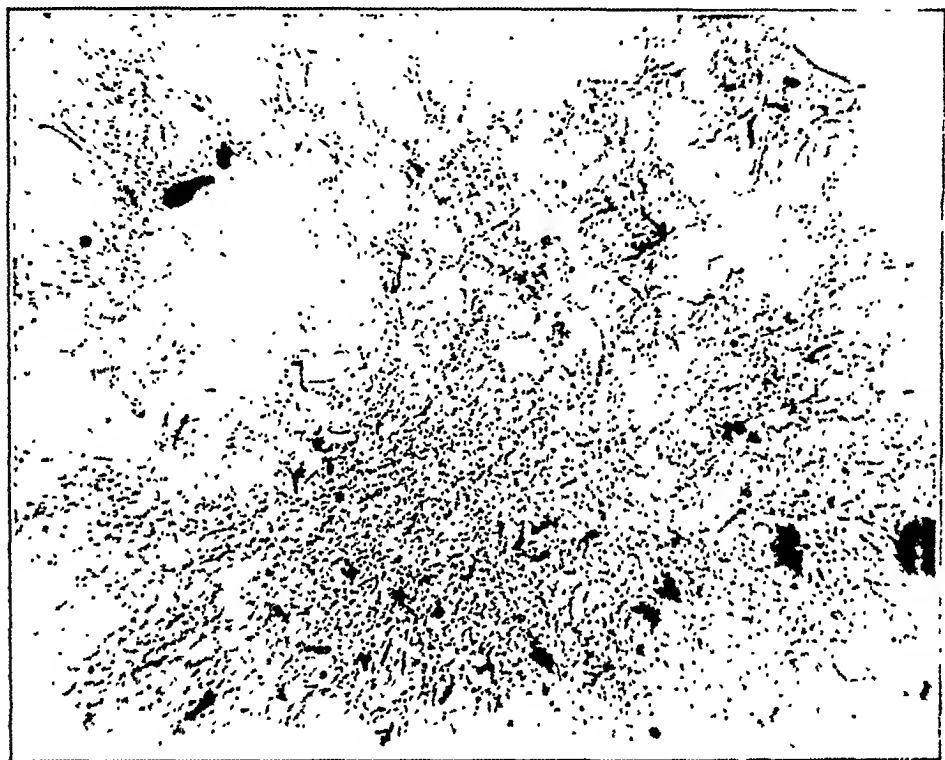


Fig. 1.—Experimental traumatic fat embolism: lung section (sudan III) from dog following multiple skull fractures.

subject demonstrate the inadequacy of the traumatic conception to cover all cases.

Carrara<sup>8</sup> reports fat embolism present at necropsy in 22 per cent of deaths from cardiovascular-renal disease and in 44 per cent of burns. Catsaras<sup>9</sup> found fat emboli in the lungs in eighteen of sixty-seven cases—

5. Sutton, G. E.: *Ann. Surg.* 76:581 (Nov.) 1922.

6. Gauss, H.: *Pathology of Fat Embolism*, *Arch. Surg.* 9:593 (Nov.) 1924.

7. Elting, A. W., and Martin, C. E.: *Ann. Surg.* 82:335 (Sept.) 1925.

8. Carrara: *Friedreich's Bl. f. gerichtl. med.* 49:, 1898, cited by Wardle (footnote 1) and Gröndahl, *Deutsche Ztschr. f. Chir.* 111:56, 1911.

9. Catsaras, J.: *Presse méd.* 28:618 (Sept. 4) 1920.



were added. There is, however, no question that necrotic muscle extract, peptone and histamine are all active in breaking down even so stable an emulsion as this.

The only difference in composition, to repeat, between emulsion A and emulsion B is in the fineness of the oil droplets. As we have said, on this fineness, among other things, hangs the stability of the emulsion. These findings, therefore, fit in with the theory of emulsions. More important for our purposes, however, they also help to explain the observations next to be detailed.

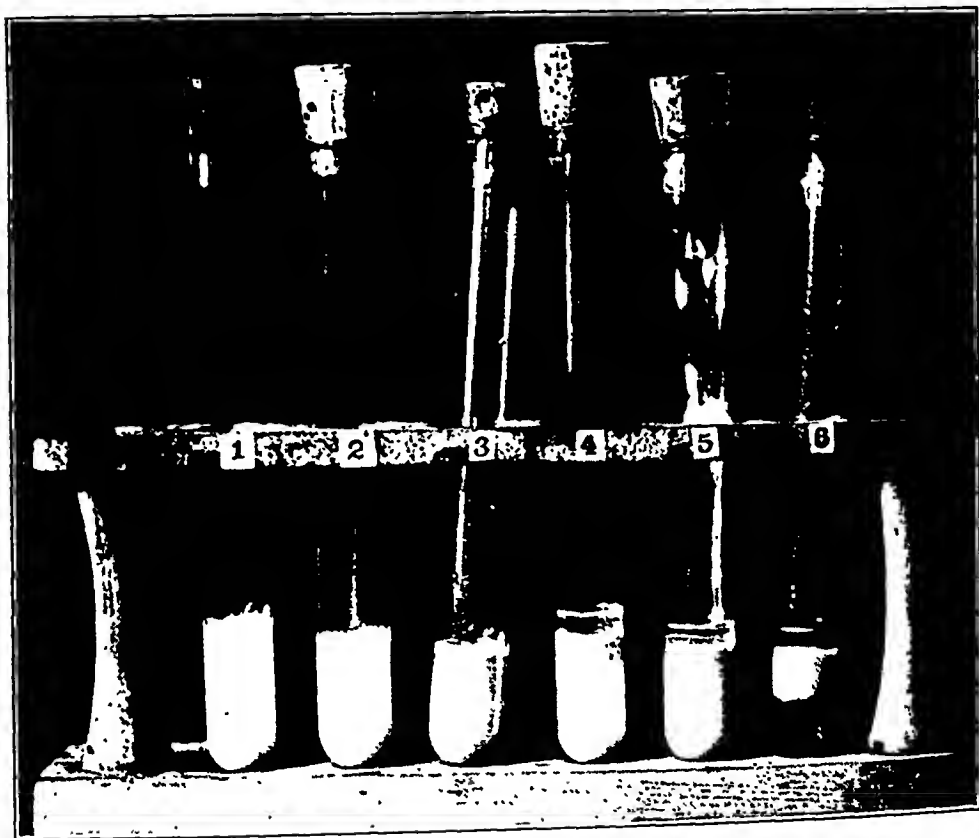


Fig. 10 (experiment 80).—Emulsion B, 5 cc., treated with reagents as follows: tube 1, 3 cc. of 0.7 per cent sodium chloride solution; tube 2, 3 cc. of saline extract of fresh muscle; tube 3, 3 cc. of saline extract of necrotic muscle; tube 4, 3 cc. of 0.2 per cent histamine solution; tube 5, 3 cc. of 1 per cent peptone solution; tube 6, 3 cc. of 2 per cent calcium lactate solution. Definite freeing of oil in tubes 4, 5 and 6; tube 3 showed a less degree of the same result although this is not obvious in the photograph; controls showed no breakdown of the emulsion; photographed at ninety-six hours.

#### EMULSION C (FIG. 11)

Theoretically an ultramicroscopic emulsion of fat in blood serum might be expected to react in a manner similar to the reaction of the coarser artificial emulsions, provided only that proper alterations in proportions are made. Actually, with one exception as described below,

(It must be remembered that marked tissue destruction is also present in many cases of fat embolism that are ascribed to traumatic origin.) These diverse types of disease have in common only the very general element of marked chemical and physical alterations of the blood.

From these observations it becomes clear that (1) fat embolism is a not infrequent finding at postmortem in a variety of conditions; (2) in many conditions in which it has been observed trauma has played no part; (3) those nontraumatic conditions in which it has occurred are largely associated with chemical or physical changes in the blood.



Fig. 3.—Experimental traumatic fat embolism: lung section (low power, color, III) from similar experiment to that shown in Figure 2.

A further fact may be here noted, namely, that in fatal traumatic fat embolism, the amount of fat found in the capillaries is sometimes disproportionately great to the amount of deep fat actually disrupted by the injury. Warthin<sup>1</sup> states, "There is no clinical correspondence between the apparent injury and the degree of the resulting hypoxia." Elting and Martin state,<sup>7</sup> "The amount of fat which may, and in fatal cases is deposited in the capillaries is apparently out of proportion to what would be regarded as the normal amount of fat in the traumatic area. Some observers have thought that there must be some other source for the free fat, but none has as yet been demonstrated."

A second possible reason for failure with emulsion C is in the enormous complexity of the external phase of the emulsion as contrasted with the simplicity of the external phase of the artificial emulsions. We are ignorant of what the effect of this difference may be on the stability of the emulsion. We attempted, however, to avoid the issue by washing the emulsion in physiologic sodium chloride solution through repeated dilution and centrifugalization. Apparently, the extreme agitation of the latter process acts much as the churn acts on cream. The emulsion agglomerated and could not again be dispersed.

A third reason lies in the possibility that some colloid other than soap is the emulsifying agent in this physiologic emulsion. Theoretically, this possibility should react unfavorably only on action by the soap precipitants. As we have said, calcium lactate may have had a slight breakdown effect on one or two occasions.

The fourth to be suggested and probably the real reason for the ineffectiveness of our reagents, lies in the fineness of the emulsion. If there is so marked a difference in the degree of reaction between emulsions A and B (figs. 6 and 10, histamine tubes), in which the difference in fineness is only moderate, then one can readily expect a much greater difference in reaction between B and C, in which the difference in the fineness is extreme. The surface tension relationships of emulsion C must demand much more marked changes in the tension of the enveloping phase than do the corresponding relationships of the coarser emulsion.

We do not feel that our experiments so far have exhausted the possibilities of demonstrating similar reactions in the plasma emulsion to those in the artificial emulsion. By other variations of the surface tension, of the  $p_H$ , of the viscosity of the blood serum, etc., it may be that the lipemic serum can be rendered sensitive to the reagents we have used. Such variations, of course, do occur in the blood stream in most conditions in which fat embolism occurs. These experiments will be undertaken as soon as opportunity arises.

We have noted one exception to the inertness of our reagents in experiments on emulsion C. That exception is the least interesting in regard to our fundamental argument, but has led to interesting *in vivo* results. The lipemic emulsion is immediately cleared with ether. This is well shown in figure 11, taken facing the light to show the transparency of the serum after treatment.

This observation is, of course, nothing new, but its application to the problem of fat embolism has led to the experimental production of fat embolism without trauma. The result will be described in the paragraphs detailing our *in vivo* experiments.

Fischer and Hooker,<sup>17</sup> in prefacing their interesting speculations on fatty degeneration, studied the formation of emulsions. The problem that faced us in regard to the origin of fat emboli from normal plasma fat was one of the breakdown of emulsions. Such a study led to interesting and suggestive results.

Emulsions are the simplest types of colloids and have been largely used, therefore, for the study of colloid behavior. They consist of two phases, an external and an internal phase, that is, the medium in which a substance is emulsified and the substance so emulsified. There is also the interphase, which is the term applied to the multiple surfaces separating the two phases. In certain emulsions this interphase is occupied by a film of a colloid such as soap. The stability of the emulsion depends on the difference in surface tension between the external and the internal phase. This, in turn, is a matter of ionic concentration on the respective surfaces, and varies inversely with the size of the emulsified droplets. In emulsions held by a colloid, it depends on the integrity of the colloid film.

From this brief consideration of the theory of emulsions it becomes evident that (1) an alteration in surface tension relationship and (2) an attack on the interphase are the two logical methods of attempting breakdown of emulsions. Dessication and other processes associated with changes of ionic concentration are the commonest examples of the former method. Precipitation of a potassium soap film with calcium salts is an example of the latter. Emulsions of oil in water will break down under treatment with a fat solvent. In addition, we have found certain reagents to be active in the breakdown of emulsions, the nature of whose action is unexplained. It is probable that these substances, histamine, peptone, necrotic muscle extract, etc., act by altering surface tension. We have in view certain experiments on surface tension to determine this point.

#### IN VITRO EXPERIMENTS

We have used three emulsions which we will designate A, B and C.

A. An ordinary emulsion of olive or cottonseed oil in water made in the proportions of 75 cc. of oil to 25 cc. of water with from 4 to 5 cc. of potassium soap added as the emulsifying agent. This emulsion is made by fractional grinding of the oil into the water in a mortar. It is fairly stable. Less than 5 per cent of the oil will separate out on standing for five days (fig. 4). Under the microscope it shows fat droplets varying from 2 or 3 microns up to large globules filling the field.

B. This emulsion differs from A only in the fineness of the droplets. It is made of olive oil and water in the same proportion but it is ground under pressure by a machine made for commercial preparation of emul-

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17. Fischer and Hooker: *Fats and Fatty Degeneration*, New York, 1917.

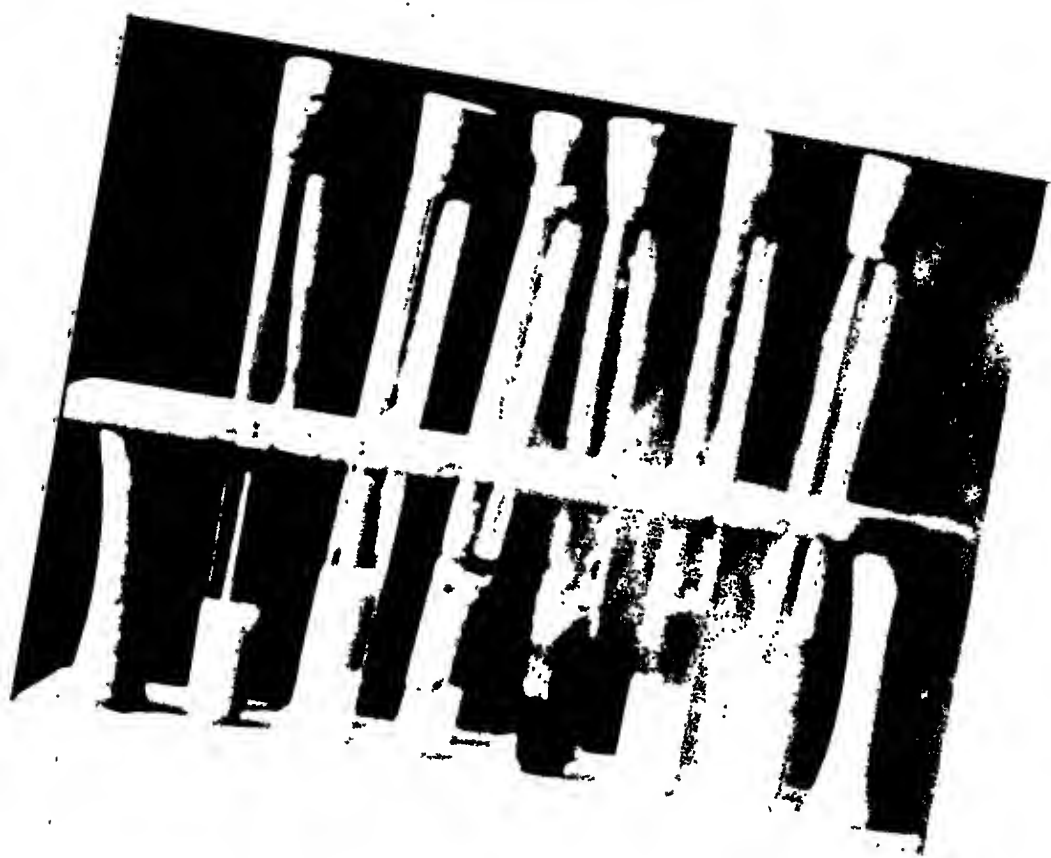
Tissue was placed in formaldehyde immediately on the death of the animal. At the end of twenty-four hours or more of hardening, it was cut by the freezing microtome, stained with sudan III, and mounted in glycerine. In removing lungs for hardening, we made comparisons in many animals between one lung from which the blood was allowed to drain and the other of which the hilum was ligated before division. In the same animal no difference between the amounts of fat in the two lungs thus treated could be detected. In later experiments, therefore, no ligation was done.

All observers agree that in any type of fat embolism, even when experimentally produced by the arterial injection of an extremity, most of the fat is found in the lungs. This is usually explained on the basis of the lower arterial pressure and the greater distensibility of the capillaries here. Whatever the cause, the lungs furnish the most useful index for the presence of fat embolism. Although kidneys, medulla and liver were preserved from most experimental animals, the conclusions of this portion of our studies are based largely on the lung findings.

Sudan III demonstrates normal fat in the lung of the dog in three different sites: 1. About the large bronchi there are often found a few cells of normal adipose tissue. 2. In the epithelial cells of the bronchial mucosa and in some animals even of the mucosa of the finer bronchioles are found droplets of fat. In cross sections of the bronchus these are not confusing, but in tangential section they may mislead the observer. 3. Finally, throughout the capillaries of the lung, most profuse in the periphery directly under the pleura, many leukocytes are found, even in dogs starved for twenty-four hours, that show ingested fat globules varying in diameter from just visible points to 3 or 4 microns. These are usually easily recognized if the observer is alert for them.

However, we have found that any or all of these normal deposits of fat may falsify results in a manner not mentioned by any previous experimenter. If the tissue is not completely frozen, the microtome knife can pick up fat droplets in passing and spread them through the section. This danger became obvious to us on one occasion when sections from the same block of tissue cut with a failing tank of carbon dioxide and with a fresh tank showed, in the first instance, what might easily pass for fat embolism and, in the second instance, nothing but the normal fat. With this experience to warn us, we took pains to insure complete solidification of the entire tissue, including the fat, before cutting.

A source of error that we controlled in many observations was the accidental presence of fat on the slides on which the sections were stained. These were frequently washed with ether before staining. We feel, however, that this is an unnecessary refinement for two reasons. In the first place, many exudates and a large proportion of the controls,



## CALCIUM LACTATE AND HISTAMINE INJECTION

Although neither calcium lactate nor histamine gave definitely positive results in destroying serum emulsions in the test tube, it was considered possible that under physiologic conditions in the blood stream, the effect observed in treatment of artificial emulsions by these reagents might be obtained. Attempts were therefore made to bathe the blood stream for a considerable period in one or the other of these substances. In order to intensify possible effects, a digestive lipemia was established. Dogs were weighed and fed from 1 to one-half pint (473.1 to 236.5 cc.) of cream. At the same time they were given 0.1 Gm. of amythal per kilogram (isoamyl ethyl barbituric acid) administered by stomach tube. Once the same dose was given by intramuscular injection somewhat later. One experiment was done under local anesthesia alone. From two to four hours after feeding, the jugular vein was exposed and a cannula inserted. Through the cannula the solution was run under gravity in small amounts at brief intervals. Injection was continued until death occurred or until at least two hours had elapsed.

There is no need to report these experiments in further detail. Three experiments were done with calcium lactate and three with histamine. In none of the six did frank unmistakable embolism occur. This group of studies was not pursued further, as our attention was diverted by the striking results obtained with ether. However, as is the case with the corresponding test tube investigations, the experiments cited are not considered exhaustive. The conditions of the experiments must be varied greatly and many more repetitions must be made before we can pronounce them completely negative. In addition, experiments with peptone, necrotic muscle extract, bile and pancreatic juice must be carried out. All these procedures are contemplated for the immediate future.

The dogs in this series that show no free fat whatever in the lungs appear among the controls for the next series of experiments (table 4).

## ETHER ADMINISTRATION

Two types of experiments were performed, namely, administration of ether (1) intravenously and (2) by inhalation. A discussion of the controls will follow the description of these experiments.

*Intravenous Ether (Tables 1 and 2).*—Seven dogs were given varying quantities of ether intravenously after a fat meal, and four starved dogs were similarly treated. The tables furnish most of the details of the experiments and their results.

Columns 1 to 4 inclusive in table I are self explanatory. Column 5 (chylomicron estimate of lipemia) records our check on the digestion and absorption of fat. As cited by Leathes and Raper,<sup>16</sup> Terroine

**Peptone:** Commercial peptone ("bacteriologic") was used in a 1 per cent solution. It appeared somewhat less efficient than either necrotic muscle extract or histamine, but definite freeing of oil never failed to occur.

**Histamine:** The instantaneous and complete breakdown of this emulsion by histamine in dilution of 0.2 per cent and even of 0.1 per cent is striking. Three cubic centimeters of histamine 0.1 per cent solution added to 5 cc. of emulsion frees all the oil before inversion of the tube can be completed (fig. 6). This observation is constant in many

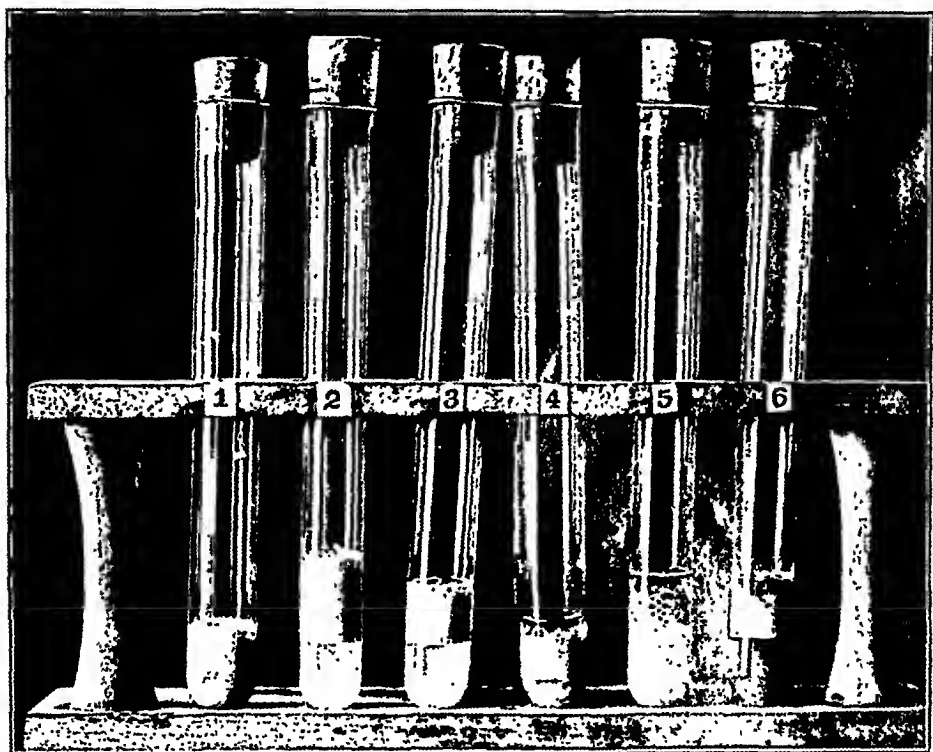


Fig. 7 (experiment 22).—Emulsion A, 3 cc., treated with reagents as follows: tube 1, none; tube 2, 3 cc. of tap water; tube 3, 3 cc. of 0.7 per cent sodium chloride solution; tube 4, 1 cc. of 1 per cent peptone solution; tube 5, 3 cc. of 1 per cent peptone solution; tube 6, 3 cc. of 1 per cent saponin. Photographed at twenty-four hours.

repetitions. The reaction of the histamine solution may also be varied on both sides of neutral (to methyl red) without effect on this property.

**Hemoglobin:** We group hemoglobin here because it is probable that the samples we used were partially decomposed with the consequent presence of histamine. The solutions had a definitely foul odor. The action was not constant, but at least partial breakdown of the emulsion came to be expected. It is interesting to observe that fresh hemoglobin as represented in fresh muscle extracts apparently had no effect.



observed differences in degree of lipemia in different dogs under similar conditions. We have in most instances made a rough estimate of the degree of lipemia following the fat meal by observing the richness of the blood in dancing particles under the dark field microscope. Columns 6 and 7 need no comment. Columns 8, 9 and 10 control the factor of possible traumatic embolism. We have remarked that concussion without fracture can produce fat embolism. We have considered it possible that the struggling of early anesthesia, retching and sharp pressure on thorax and abdomen (as in artificial respiration) might conceivably have similar effects. The amount of trauma (column 10) is recorded as "very slight" when only the struggling, attendant on induction of anesthesia, occurred, and as "slight" when either of the other two factors was present. Incision into fat tissue in the neck to expose the jugular vein is a constant concomitant of these experiments and adds a minute traumatic element. The occurrence of vomiting (column 8) is a check

TABLE 2.—*Results of Intravenous Ether Anesthesia in Dogs Starved Twenty-Four Hours*

Dog	Weight of Dog in Kg.	Chylomliron in Estimate of Lipemia	Duration of Anesthesia	Quantity of Ether Administered	Amount of Vomiting	Amount of Artificial Respiration	Amount of Trauma	Amount of Pulmonary Edema	Amount of Fat Embolism
23	6	Extremely light	43 minutes	7 cc.	None	None	Very slight	Slight	Very few emboli
24	13	Extremely light	50 minutes	23 cc.	None	None	Very slight	Fatal	No emboli
25	5	Extremely light	39 minutes	6 cc.	None	None	Very slight	Fatal	A few emboli
41	8	Extremely light	18 minutes	5 cc.	None	5 minutes	Slight	Slight	Many emboli

also on the possibility that fat found in the lungs might have been aspirated. Column 11 (amount of pulmonary edema) records an interesting finding. Eight of the eleven dogs died unquestionably from pulmonary edema and in the remaining three dogs pulmonary edema was definitely present. This effect of intravenous ether is in striking contrast to the effects observed in the dogs given prolonged inhalation anesthesia (table 3). In none of the latter was the edema fatal. In the intravenous experiments, frothy pink fluid to the amount of 100 cc. or more poured from the nose and mouth. This pulmonary edema is not to be confused with that frequently described as associated with fat embolism. It is purely toxic in origin. The reason for this assertion is that the degree of fat embolism produced in these dogs did not even approach that which can be caused by intravenous injection of oil without the production of edema. Column 12 can best be understood by referring to the paragraphs above on the criteria for diagnosis of fat embolism.

When we survey this table, judgment must be reserved on the possible sources of error until the discussion of controls (table 4) has been read.

Table 2 needs no comment other than that given for the corresponding columns above in table 1.

The emulsion was treated on one occasion with the serum of a dog dead of experimental intestinal obstruction (fig. 5) and with the content of the obstructed loop. The result was a partial breakdown of the emulsion. This is recorded here only as a single observation which may confirm other analogous observations but on which, by itself, no weight should be put.

**Other Substances:** In one observation of pancreatin (commercial) and one of fresh pancreatic juice of the dog, there was complete breakdown of the emulsion (fig. 5).

**Fresh Dog Bile:** In two observations there was partial breakdown of the emulsion (fig. 6).

**Sodium Taurocholate and Sodium Glycocholate (2 per cent solution):** In one observation there was no breakdown of the emulsion (fig. 6).

**Saponin:** In three observations of a 1 per cent saponin solution, partial breakdown of the emulsion occurred twice (fig. 7).

**Glucose:** One observation was made with a 10 per cent solution of glucose prepared for intravenous medication. There was moderate breakdown of the emulsion.

#### EMULSION B (FIG. 10)

Most of the foregoing reagents were tested repeatedly with the finer type of emulsion. The soap precipitants, hydrochloric acid and the various products of protein decomposition acted in a similar manner to emulsion A, except as noted below. Pancreatic juice, bile and bile salts were not employed. It was found that ether acts quite otherwise than with the coarse emulsion. The addition of ether immediately results in a gel resembling petroleum jelly, which is permanent on long standing in the test tube. If it is spread out on a flat surface, the ether rapidly evaporates, freeing the oil and water. If a large excess of ether is used, e. g., 20:1, the gel is fine and flocculent and, in the course of a half-hour, disappears. Evaporation of the ether then leaves the oil and water in separate layers. If the ether is poured from the gel in the test tube and more ether is added, the oil fraction of the gel may promptly go into solution. In other words, the ultimate fate of the emulsion, when treated with ether with evaporation permitted, is destruction.

The striking difference in reaction between this emulsion and emulsion A is in the speed and completeness of the breakdown. Whereas the most active agent we studied, histamine, will destroy emulsion A in a few seconds, equal proportions will take several minutes to effect a change in emulsion B, and the freeing of the oil even after days is rarely complete. A layer of untouched emulsion lies between the watery layer below and the layer of oil above. This difference is well illustrated in figure 10, which was photographed ninety-six hours after the reagents

studies report a diminution of chylomicron counts during ether anesthesia. This finding has been confirmed by us in the next series of experiments to be reported. Bloor, on the contrary, found a rise of as much as 50 per cent in the blood fat during ether administration using chemical methods. These two findings, considered contradictory by Schroeder and Holt, are really not so. The diminution in chylomicron count does not mean diminution in blood fat. The physical state of the fat is simply altered so that it is no longer visible as chylomicrons. A diminution of chylomicron count can proceed simultaneously with an increase in total blood fat, and to accept Bloor's results, probably does. This increase in

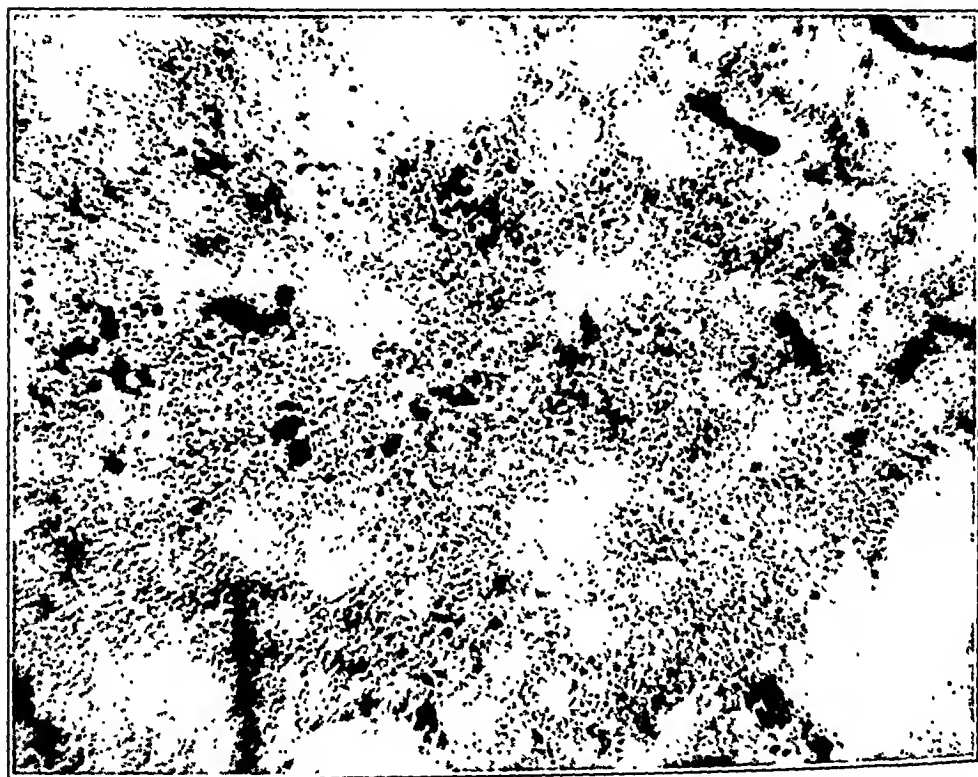


Fig. 12.—Lung of dog 18 after intravenous ether, under low power (sudan III).

fat may be due to the solution of depot fat by the ether vapor circulating with the blood. If fat is so dissolved, then its relation to the lowering of the ether vapor tension in the blood is exactly the same as that of the dissolved chylomicron fat. That is, fat emboli would result. In other words, somewhat less fat is available in the starved dogs than in the fat fed dogs; but enough fat can be taken up by the circulating ether vapor to create embolism.

Examination of these lungs stained with sudan III (figs. 12 and 13) shows not only the ordinary drops that fill capillaries but also a type of much finer droplet from about 2 to 7 microns in diameter. These are

we were able to demonstrate no definite result with any of our reagents. On two occasions there was a doubtful freeing of fat following the addition of calcium lactate, and a similar doubtful change following the addition of a crystal of histamine.

Many reasons for this failure can be suggested. In the first place, technical difficulties are great. When the lipemic serum stands, the emulsion rises to the top within a few hours as a cream, which consists, at first, entirely of ultramicroscopic particles, the chylomicrons of Gage and Fish.<sup>18</sup> In the course of days, possibly from dessication, possibly

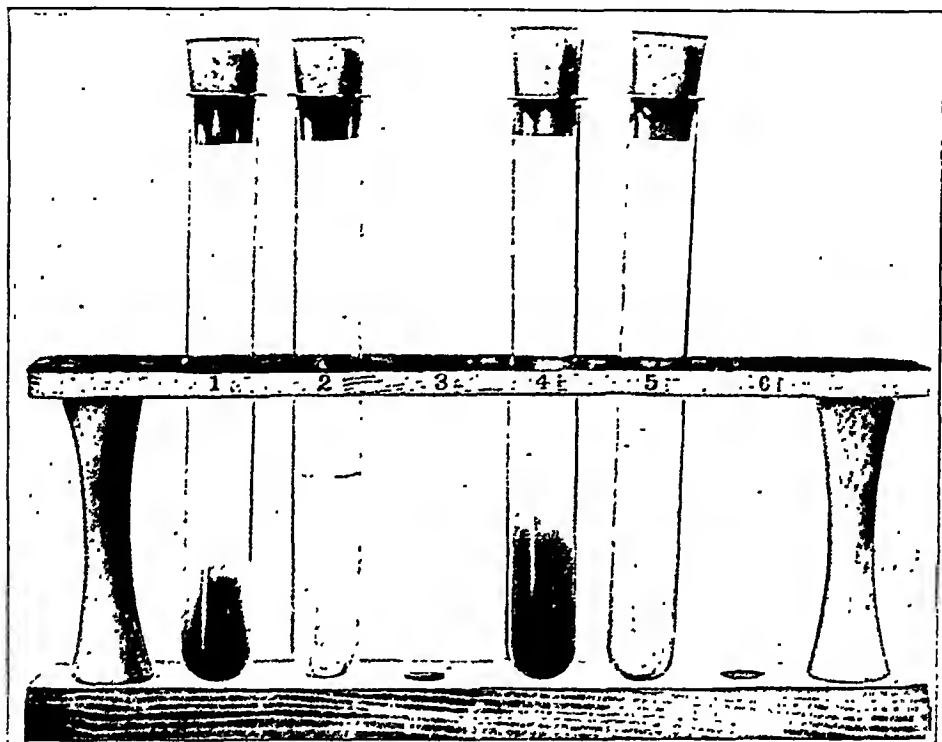


Fig. 11 (experiment 79).—Emulsion C (lipemic serum): this photograph was taken with a yellow screen and facing the light to show changes in transparency; the left tube of each pair shows the untreated emulsion; the right tube shows the emulsion treated with ether.

from putrefactive changes in the serum, possibly from other causes, free fat appears spontaneously. This, of course, confuses the reading of the experimental tubes. We have attempted to overcome this difficulty by using micro methods of reading within twenty-four hours of the experiment. Staining the cream for fat and observation under the darkfield microscope gave no added information. Attempts to demonstrate differences in the "greasiness" of the emulsion by allowing it to soak into paper were equally without result.

18. Gage and Fish (footnote 15, second reference).

## PROTOCOL

EXPERIMENT 84.—Dog 47; April 10, 1926; weight, 6 Kg.

- 10:00 a. m. Given one-half pint (236.5 cc.) of cream by stomach tube.  
12:00 m. Ether anesthesia begun; no retching or violent struggling.  
12:30 p. m. Heavy grade lipemia. (This, and corresponding observations below, refer only to chylomicron estimates under the dark field microscope.)  
1:45 Still heavy lipemia.  
2:45 Moderately heavy lipemia.  
5:10 Moderate lipemia.  
5:30 Anesthesia crowded to fatal termination.  
Total: 5½ hours; 21-22 ounces (621-650 cc.) of ether.

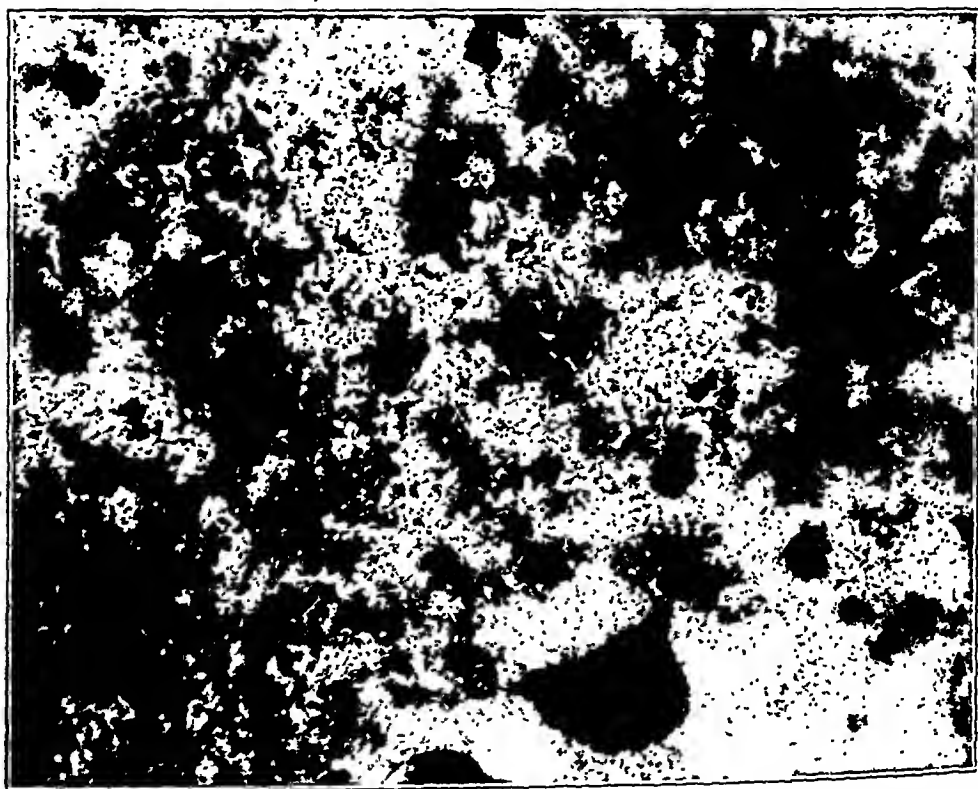


Fig. 14.—Lung of dog 47 after inhalation ether, under high power (sudan III).

Throughout the entire period of the anesthetic there was no dyspnea, no increase in respiratory effort and no vomiting or retching. The dog's tongue was kept forward with a hemostat. The corneal reflex was present at all times. Early in the experiment a 2 cm. linear incision was made through the skin in the inguinal region and a blood drop was secured for estimate of lipemia by cutting a minute subcutaneous vessel. No appreciable loss of blood occurred. There was no disturbance of any fat depot.

The lungs were removed without ligation of the hilum and placed in formaldehyde.

Microscopic examination with sudan III showed areas of embolic fat (figs. 14 and 15).

## SUMMARY OF IN VITRO EXPERIMENTS

1. Artificial soap-held emulsions of oil in water are destroyed, among other substances, by four classes of reagents, viz., (a) fat solvents, (b) soap precipitants, (c) acids and alkalis and (d) products of protein decomposition.

2. The rapidity and completeness of the effect varies with the fineness of the emulsified oil. The finer the emulsion, the less efficient is the reagent.

3. The physiologic emulsion of fat in blood serum seems to be destroyed only by the fat solvents.

4. On a theoretical basis no good reason for this difference can be adduced, except the greater fineness of the lipemic emulsion. Experiments on points 3 and 4 are not yet complete.

## IN VIVO EXPERIMENTS

Recapitulation of the results of study of the literature and of our test tube experiments leads to three important conclusions, viz., 1. Not all fat embolism is of traumatic origin. 2. The normal emulsion of fat in the blood stream is a possible source of fat in nontraumatic fat embolism. 3. The action of certain substances which are present in the blood stream in pathologic states offers, on the basis of experiments with artificial emulsions, a possible mechanism for the freeing of this fat from the emulsified state. Attempts to demonstrate the operation of this mechanism in the blood serum in vitro have not succeeded.

Attempts to produce nontraumatic fat embolism in vivo may be divided into two groups. In the first of these, calcium lactate and histamine, substances not definitely effective in vitro, were employed. In the second we made use of ether, which gave positive results in the test tube.

Before we detail these experiments, it is important to define technical procedures and standards on which estimation of the results depends. An experience covering the examination of over 250 microscopic sections for fat has shown us that decision on the presence or absence of fat embolism is not always easy. Certain pitfalls into which many observers have undoubtedly fallen are mentioned by some experimenters, particularly Caldwell and Huber.<sup>19</sup>

The problem of staining on which many authors lay stress has not offered difficulties to us. Throughout we have used sudan III in the form of a saturated solution in 70 per cent alcohol. In every section examined, normal fat in the tissue such as that described below, took the stain clearly and thereby automatically controlled the staining of pathologic fat.

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19. Caldwell and Huber (footnote 4, sixth reference).

These experiments confirm the finding that ether vapor in the blood stream will produce fat embolism, at least in the presence of digestive lipemia. They further show that the introduction of ether by inhalation is possibly more effective than by intravenous injection. Dog 46 (figs. 16 and 17) showed throughout both lungs at least as great a degree of embolism as we have produced with the intravenous injection of pure olive oil in amounts of 1 cc. per kilogram, and dog 52 showed almost as much. Both of these were far greater than anything seen with intravenous ether. Figures 18 and 19 show lung fields from two other dogs of this series. Figure 19 from the lung of dog 50 illustrates what is meant by the description in table 3—"a few emboli."

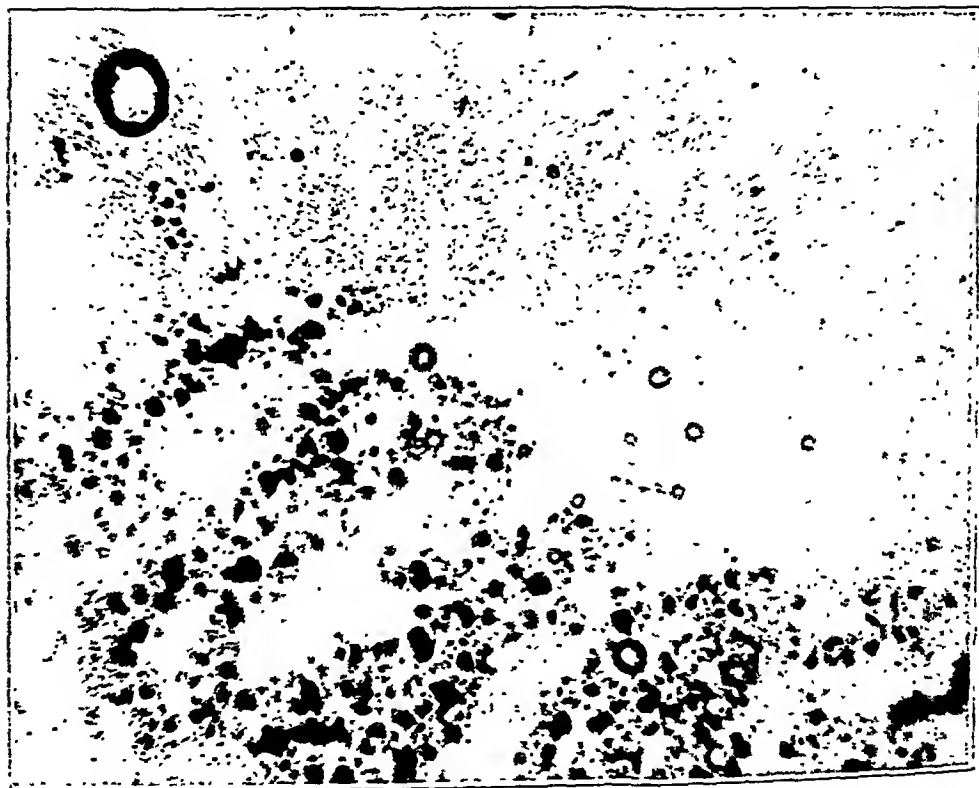


Fig. 17.—Kidney of dog 46 after inhalation ether, under low power (sudan III).

The reason for the difference between the results in the intravenous and in the inhalation methods of administration is probably the fact that in the former the blood stream was bathed in ether for a shorter period than in the latter. The toxic effect of intravenous ether on the lung rapidly produces a pulmonary edema that cuts short the experiment at a relatively brief period by killing the animal.

One experiment (dog 51) was done with a short ether anesthesia of fifteen minutes. An interesting finding here, in addition to the occurrence of embolism, was that the embolic fat was on the average in a much finer state of division than in any other dog of this series. In other words, the process of agglomeration had not had time to progress far.

were stained on unprepared glassware with negative results. In the second place, our criteria for positive results as outlined in the next paragraphs automatically rule out accidental droplets.

With these sources of possible error in mind, the interpretation of stained fat not in the three sites mentioned is often difficult. To guide us in deciding whether or not fat droplets seen in lung sections were embolic fat, we took into consideration in every instance (1) the amount of free fat seen; (2) its distribution in sections taken from different areas of both lungs; (3) its distribution in any one section in relation to bronchi, and (4) its unequivocal presence in capillaries.

No lung was considered to present evidence of fat embolism on the basis of one or two fat droplets to a section. The sources of error described could easily account for that amount. In addition no measurement of the amount of trauma that will liberate fat has been or can easily be made. All the dogs were subjected to trauma, if one includes in that term the amount of constraint necessary to control a dog struggling under an anesthetic. Such slight mechanical disturbance might account for minimal freeing of fat from the depots. A profuse amount of fat was usually unequivocal. In between these two grades there were a few animals in which the other criteria governed.

A diagnosis of fat embolism was made only if fat droplets were found in almost all fields in at least three sections from different areas of the two lungs. The distribution of emboli, even in the experimental injection of fat, is irregular. Some sections will be rich in fat, others will show little or none. For that reason one or two negative sections do not invalidate three or more positive sections. In the same sense, negative fields in an otherwise positive section are not of importance. The more sparse the fat, the more thoroughly we insist on wide distribution before diagnosing embolism.

In certain sections, the fat observed was found to be in fairly close relation to large bronchi. This fat was ignored in making the diagnosis. There was a possibility that it might have been spread by the microtome knife, or that it might be in the mucosa of a branch bronchus approaching the main stem and cut tangentially. Particularly in the fat fed dogs it might represent intragastric fat, vomited and aspirated. In one animal this had undoubtedly occurred.

Finally, no diagnosis of fat embolism was made unless the section showed definitely that some of the fat was in the capillaries. It need not all be in the capillaries, as embolic fat rapidly passes into the alveoli. Warthin<sup>1</sup> made use of this fact in diagnosing fat embolism clinically from the presence of fat in the sputum.

The absence of fat embolism as exemplified by control experiments will be taken up when they are discussed.



Five of the nine dogs in this series had repeated estimations of chylomicrons in the blood throughout the course of the anesthesia. In all there was a gradually diminishing number.

What has been said as to the probable mechanism of the appearance of emboli following intravenous injection of ether will hold in regard to the inhalation experiments. The method of introduction of the ether into the blood stream is immaterial.

*Controls* (table 4).—The presence of fat embolism in the experimental dogs is for the most part unmistakable. Certain of them, however, showed minimal degrees. What degree of trauma will cause a minimal degree of fat embolism is not known. What alterations in chemical and physical characteristics of the blood will do the same is equally unknown. That normal blood with moderate fat content shows

TABLE 4.—Control Dogs

Dog	Weight in Kilo- grams	Amount of Cream Fed	Chylomieron Estimate of Lipemia	Anesthesia Used	Mode of Death	Amount of Trauma	Amount of Fat Embolism
1	10	None	Not done	Ether 20 hours before death	High intestinal obstruction	Moderate	No emboli
9	3.3	None	Not done	0.3 Gm. Barbituric acid derivative	Histamine intravenously	Slight	No emboli
10	10	None	Not done	1 Gm. Barbituric acid derivative	Bled to death	Slight	No emboli
11	6	$\frac{3}{4}$ pint	Not done	Local	Bled to death	Slight	No emboli
7	10	1 pint	Not done	Local	Bled to death	Slight	No emboli
8	8	$\frac{3}{4}$ pint	Not done	0.8 Gm. Barbituric acid derivative	Bled to death	Slight	No emboli
2	10	1 pint	Not done	1 Gm. Barbituric acid derivative	Calcium lactate intravenously	Slight	No emboli
3	10.5	1 pint	Not done	1 Gm. Barbituric acid derivative	Histamine intravenously	Slight	No emboli
4	10	1 pint	Not done	1 Gm. Barbituric acid derivative	Bled to death	Slight	A few emboli
5	10	1 pint	Not done	1 Gm. Barbituric acid derivative	Bled to death	Slight	A few emboli
43	8	$\frac{1}{2}$ pint	Heavy	Local	Bled to death	Slight	No emboli
55	8	$\frac{1}{2}$ pint	Light	None	Sodium cyanide	Slight	Many emboli
56	8	$\frac{1}{2}$ pint	Heavy	None	Sodium cyanide	Slight	No emboli
57	6	$\frac{1}{2}$ pint	Very heavy	None	Sodium cyanide	Moderate	No emboli

no free stainable fat is certain. Whether the same is true of blood with a rich digestive lipemia is a question that must be answered. It is impossible to cause the death of an animal without both trauma, even if slight in amount, and chemical alteration of the blood. In the lipemic plasma, the effect of the latter in causing embolism will be magnified. Each dog in the experimental series, therefore, represents a complex of different possible causes of fat embolism. The dogs showing relatively slight embolism need the strictest controls.

On account of the probably multiple factors that may cause fat embolism, a series of control animals need not show absolute freedom from this finding. It will suffice to establish the validity of the experiments if dogs given ether show a decidedly higher embolic rate than do dogs killed in all other ways.

TABLE 1.—Results of Intravenous Ether Anesthesia in Fat Fed Dogs

Dog	Weight Kilo- grams	Amount of Cream Fed	Interval Between Feeding and Beginning of Anesthesia	Chylomicron Estimate of Lipemia	Duration of Anesthesia	Quantity of Ether Admin- istered	Amount of Vomiting	Amount of Arti- ficial Res- piration	Amount of Trauma	Amount of Pulmonary Edema	Amount of Fat Embolism
17	7	½ pint	1 hour, 30 minutes	Moderate	1 hour, 30 minutes	11 cc.	None	1 minute	Slight	Fatal	A few emboli
18	8	½ pint	1 hour, 15 minutes	Moderate	34 minutes	7.5 cc.	None	3 minutes	Slight	Fatal	Many emboli
20	6	½ pint	1 hour, 40 minutes	Light	11 minutes	8 cc.	None	None	Very slight	Moderate	A few emboli
21	7	½ pint	1 hour, 30 minutes	Moderate	32 minutes	10 cc.	None	None	Very slight	Fatal	Many emboli
22	7	½ pint	1 hour, 15 minutes	.....	42 minutes	9 cc.	None	None	Very slight	Fatal	Many emboli
40	7.5	½ pint	1 hour, 20 minutes	.....	1 hour, 30 minutes	13.5 cc.	None	2 minutes	Slight	Fatal	Many emboli
42	8	½ pint	2 hours, 30 minutes	Moderate	1 hour, 16 minutes	6 cc.	None	None	Very slight	Fatal	Many emboli

TABLE 3.—Results of Inhalation Ether Anesthesia in Fat Fed Dogs

Dog	Weight Kilo- grams	Amount of Cream Fed	Interval Between Feeding and Beginning of Anesthesia	Chylomicron Estimate of Lipemia	Duration of Anesthesia	Quantity of Ether Admin- istered	Amount of Vomiting	Amount of Arti- ficial Res- piration	Amount of Trauma	Amount of Pulmonary Edema	Amount of Fat Embolism
16	12	½ pint	1 hour	Moderate	6½ hours	1,000 cc.	None	None	Very slight	Slight	Very many emboli
17	6	½ pint	2 hours	Heavy	5½ hours	600 cc.	None	None	Very slight	None	Many emboli
18	8	½ pint	1 hour, 15 minutes	Very heavy	6¾ hours	400 cc.	None	None	Very slight	Slight	Many emboli
19	7	½ pint	1 hour, 20 minutes	Heavy	6¾ hours	500 cc.	Considerable	3 minutes	Moderate	Moderate	A few emboli
50	11	½ pint	1 hour, 30 minutes	Heavy	6½ hours	400 cc.	None	3 minutes	Slight	Moderate	A few emboli
51	5	½ pint	2 hours	Heavy	¼ hour	30 cc.	None	None	Moderate	None	Many emboli
52	11	½ pint	2 hours	Very heavy	5¾ hours	500 cc.	None	5 minutes	Slight	Marked	Very many emboli
53	9	½ pint	2 hours	Very heavy	1¾ hours	100 cc.	None	None	Very slight	Marked	Very many emboli
54	7	½ pint	2 hours	Moderate	5¾ hours	500 cc.	None	6 minutes	Slight	Slight	Many emboli

## GENERAL CONCLUSIONS OF PART I

To put the results of this study in general terms, we have shown that the blood fat (and possibly also the nontraumatized depot fat) is a source of fat in fat embolism, and we have demonstrated one means by which the blood fat can be made to become embolic; namely, by the administration of ether. We have further presented evidence suggesting other mechanisms by which the same result might be expected to be brought about, mechanisms that undoubtedly are available in the body in many cases of fat embolism; namely, the action of products of protein decomposition. We have indicated the path of future experimentation to prove or disprove the actual causation of fat embolism by this means.

The significance of these findings is both theoretical and practical. Three practical considerations may be presented.

1. *Fat Embolism and Ether Anesthesia in Clinical Surgery.*—It is not at all improbable that certain ether deaths after prolonged anesthesia may have been caused by fat embolism, by exactly the mechanism we have demonstrated. That more such deaths have not occurred may be due to the general practice of starvation before ether anesthesia, a starvation that has been imposed for other reasons. It is possible, also, that a proportion of postoperative pulmonary complications, usually ascribed to thrombotic emboli, may actually be the result of fat emboli in the lungs. Certainly, these possibilities are suggestive enough to offer another sound reason for starvation previous to ether anesthesia.

2. *Fat Embolism and Intravenous Medication.*—The literature of fat embolism in poisonings and the results of our test tube experiments strongly suggest that the physical state of the blood fat should receive consideration in every instance in which medicaments are introduced into the blood stream. Certainly, the effect of such treatment of the blood on the physical state of the blood fat has received no consideration. Even in such exhaustive studies as that of Hanzlik and his co-workers,<sup>23</sup> who observed many physical and chemical changes in the blood after scores of different agents were introduced intravenously, no mention is made of the possibility of any change in the plasma emulsion, much less of any symptoms arising therefrom. It is conceivable that certain injection reactions may be induced by this mechanism. One would do well, until this point is proved or disproved, to inject no untried substance except when the plasma fat content is minimal.

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23. Hanzlik, P. J., and Karsner, H. T.: *J. Pharm. & Exper. Therap.* **23**:173 (April) 1924. Hanzlik, P. J.; De Eds, F., and Tainter, M. L.: *Blood and Symptomatic Changes Following Intravenous Administration of a Variety of Agents and Solutions*, *Arch. Int. Med.* **36**:447 (Oct.) 1925.

A sample protocol follows:

#### PROTOCOL

EXPERIMENT 75.—Dog 42; March 31, 1926; weight, 8 Kg.

- 11:00 a. m. Given one-half pint (236.5 cc.) of thin cream; drank it promptly.  
 2:00 p. m. Ether anesthesia; femoral vein exposed.  
 2:05 Moderate number of chylomicrons in dark field examination of blood.  
 2:06 Mask ether stopped; intravenous ether, 0.5 cc.  
 2:10 Ether intravenously, 0.5 cc.  
 2:12 Ether intravenously, 0.5 cc.  
 2:15 Ether intravenously, 0.5 cc.  
 2:16 Ether intravenously, 0.5 cc.  
 2:18 Ether intravenously, 0.5 cc.  
 2:20 Ether intravenously, 0.5 cc.  
 2:22 Ether intravenously, 0.5 cc.  
 2:26 Ether intravenously, 0.5 cc.  
 2:28 Ether intravenously, 0.5 cc.  
 2:40 Ether intravenously, 0.5 cc.  
 2:53 Ether intravenously, 0.5 cc.  
 3:10 The dog died suddenly. On suspending it by the hind legs, frothy pink fluid ran from the mouth. This showed fat globules on staining with sudan III. However, it was contaminated by buccal content.

Necropsy: The lungs showed typical changes of pulmonary edema, most marked at the bases; they were removed without ligation of the hilum.

Microscopic examination with sudan III revealed many fat emboli.

These experiments have demonstrated to our satisfaction that fat embolism can be produced experimentally by the intravenous injection of ether. We believe the mechanism to be that of the test tube. The ether in the blood stream takes into solution the circulating emulsified droplets. As the ether vapor passes into the alveoli, the ether vapor tension in the blood is lowered to a point at which the fat comes out of solution as free fat. The emulsifying power of the blood is not sufficient, particularly in the slowly moving capillary bed of the lung, to reform the original fine emulsion. Fat emboli visible under the ordinary microscope thus appear.

It may be asked whence in the starved dogs enough fat can accumulate to produce any embolism. The degree of embolism in the starved dogs is seen, on the average, to be much less than in the fat fed dogs (tables 1 and 2). A possible explanation for embolism in the starved dog may be found by comparing the results of Bloor's chemical analyses of the blood under ether anesthesia,<sup>20</sup> with the results of chylomicron observations by Day<sup>21</sup> and by Schroeder and Holt.<sup>22</sup> The latter two

20. Leathes and Raper (footnote 16, p. 162).

21. Day, M. G.: *Am. J. Surg.* **36**:53 (April) 1922, cited by Schroeder, L. C., and Holt, E.: Chylomicron (Free Fat) Content of Blood in Infants. *Am. J. Dis. Child.* **31**:201 (Feb.) 1926.

22. Schroeder and Holt (footnote 21).

vein of a dog and produced fatal fat embolism which was accompanied by acute pulmonary edema. Scriba (1879),<sup>24</sup> after experimental observations, pointed out that a drop of fat could pass through the lungs without difficulty; previously a patent foramen ovale had been considered essential to the passage of embolic fat from the lesser to the greater circulation. Riedel (1877)<sup>25</sup> injected oil into an artery, getting the most extensive embolism in the lung after the oil had passed through the other organs. He mentioned two factors in explanation: (1) the lower blood pressure in the pulmonary circulation, and (2) the lack of supporting tissue about the tortuous pulmonary capillaries.

Scriba,<sup>24</sup> noting the large amount of oil that could be injected without fatal effect, attempted to establish a ratio between the fatal dose and the amount of the depot fat. He calculated the fat content as 71 Gm. in a human femur, as 12.7 Gm. in that of a 17 Kg. dog and as 1.3 Gm. in that of a 2 Kg. rabbit. He found that a dog showed no threatening symptoms until one third of the entire body fat mass had been injected at one sitting and reported a similar relationship in the rabbit. Ribbert (1894),<sup>26</sup> estimated the fatal human oil dosage as 30-40 cc., but Landois (1923,<sup>2</sup>) accepting Scriba's ratio, computed the fatal human dose at 210 cc. Fibiger (1901)<sup>27</sup> reported the accidental injection of 50 cc. of oil into the vein of a young adult man; the victim died. Fibiger ascribed the death to fat embolism. Fuchsig (1902)<sup>28</sup> reported the fatal intravenous olive oil dosage for dogs as 2 Gm. per kilogram. Wegelin (1913),<sup>29</sup> after reference to the contention of Merckel that intravenous oil injection in dogs justified no conclusions as to human embolism, reported the work of Kojo on the relative effects of various oils. Kojo found that in rabbits an intravenous injection of from 0.6 to 0.7 cc. of olive oil per kilogram was well borne. A dose of 0.85 cc. per kilogram paralyzed the hind legs with recovery, whereas from 1 to 1.5 cc. per kilogram caused death. Using rabbit fat in the place of olive oil, he found 0.5 cc. per kilogram definitely fatal. Human fat in a dosage of 0.5 Gm. per kilogram was well borne, but 1 Gm. of human fat per kilogram would regularly cause death. The olive oil, Kojo found, went over into the greater circulation in considerable amount; rabbit fat injection gave only pulmonary embolism and human fat seemed to occupy an intermediate place as regards viscosity. Kojo found the reabsorption of emboli complete in three weeks. The homogenous fat was reab-

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24. Scriba: *Deutsche Ztschr. f. Chir.* 12:118, 1879.

25. Riedel: *Deutsche Ztschr. f. Chir.* 8:571, 1877.

26. Ribbert: (Footnote 4, second reference.)

27. Fibiger, cited by Gröndahl (footnote 10) and others.

28. Fuchsig, cited by Warthin (footnote 1).

29. Wegelin, C.: *Schweiz. med. Wchnschr.* 53:133 (Feb. 8) 1923.

found richly scattered in capillaries, and can be observed only by the higher power lenses. A few such droplets can be made out in figure 13. They are interpreted as an intermediate stage in the agglomeration of fat. They can therefore be regarded as presenting evidence confirmatory of our conception of the mechanism of production of fat embolism by ether administration.

We emphasize at this point one fact, namely, fat embolism has been produced by intravenous ether administration, whatever weight one may care to place on the theoretical considerations discussed.

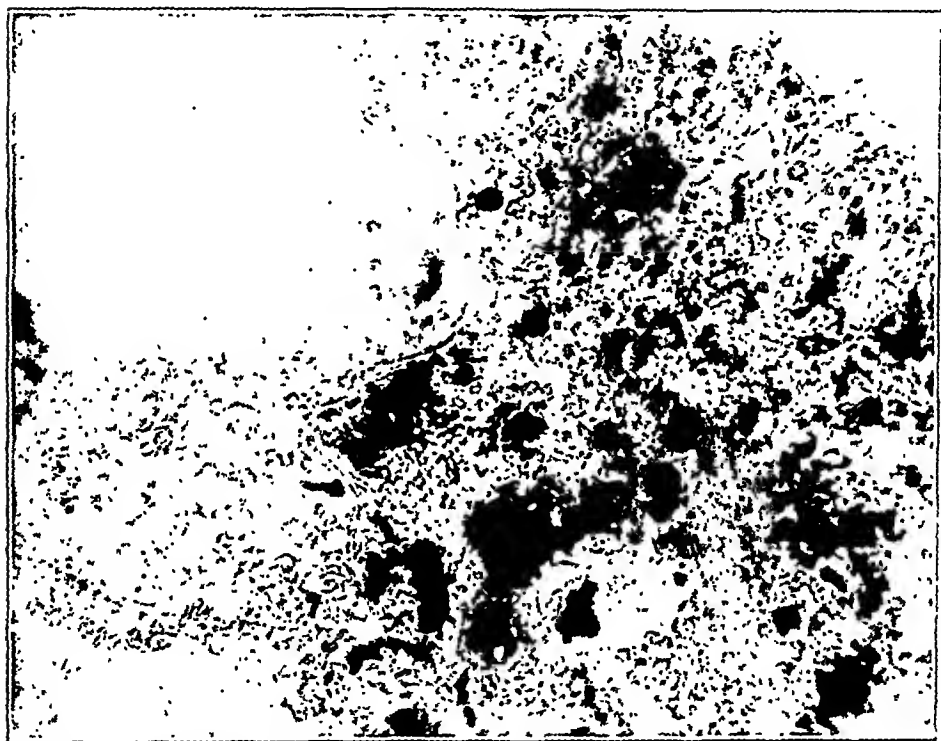


Fig. 13.—Lung of dog 40 after intravenous ether, under high power (sudan III).

*Ether by Inhalation* (table 3).—The technic of these experiments is of the simplest order. Nine observations were made. In all of these conditions were rendered favorable for ether action by creating a digestive lipemia. Table 3 records the varying conditions of the nine experiments. The column headings need no explanation further than that given for table 1.

A sample protocol follows:

dogs that received 1.5 cc. per kilogram or less survived or were killed when in good health, for other reasons. Three of these six were allowed to survive and at the date of writing have remained in good health for more than two months. The dog that received the smallest dose, 0.34 cc. per kilogram, died spontaneously at the end of six weeks from lung suppuration. This dog was never robust and showed symptoms, diarrhea and a hacking cough, within ten days of injection. It is possible that an organism of low virulence was introduced with the oil by a break in aseptic technic. Certainly death can hardly be ascribed to the mechanical effect of the oil in view of the other results. It seems probable from these figures that the dog will tolerate an injection of sterile cottonseed oil intravenously to the amount of 1.5 cc. per kilogram.

TABLE 6.—*Results of Intravenous Injection of Sterile Cottonseed Oil in Dogs*

Dog	Weight in Kilograms	Amount of Oil Injected, Cc.	Dosage of Oil per Kilogram, Cc.	Dogs Died Spontaneously	Dogs Killed Experimentally	Dogs Surviving
27	7.6	23.0	3.0	At 1 hour	.....	.....
35	10.0	25.0	2.5	At 3 to 12 hours	.....	.....
36	12.2	21.5	2.0	At 3 to 12 hours	.....	.....
32	5.0	8.5	1.7	At 11 days	.....	.....
34	11.5	20.0	1.66	At 18 days	.....	.....
26	10.0	15.0	1.5	.....	Killed by pneumothorax at 1 hour	.....
31	6.0	9.0	1.5	.....	.....	Living and well at 72 days
37	8.6	13.0	1.5	.....	.....	Living and well at 59 days
33	7.5	9.0	1.2	.....	.....	Living and well at 67 days
29	5.4	4.5	0.83	.....	Killed at 7 days	.....
30	5.0	4.0	0.8	.....	Killed at 7 days	.....
28	6.2	2.1	0.34	At 43 days	.....	.....

Figures 20, 21 and 22 show the amount of fat respectively in the lung, medulla and kidney of dog 27, which died an hour after injection of 3 cc. of cottonseed oil per kilogram. They are interesting chiefly for comparison with the photomicrographs of nontraumatic fat embolism caused by ether administration. Figures 23 and 24 show the amount of fat that may remain in the capillaries of the lung and kidney a week after injection. This dog (dog 30) received only 0.8 cc. of cottonseed oil per kilogram. It was killed at seven days for the purpose of estimating the rate of disappearance of the oil from the blood vessels. We are not reporting at this time the pathologic observations on the dogs dead following oil injections on account of the small number available for study.



Fig. 15.—Lung of dog 47 after inhalation ether, under high power (sudan III).

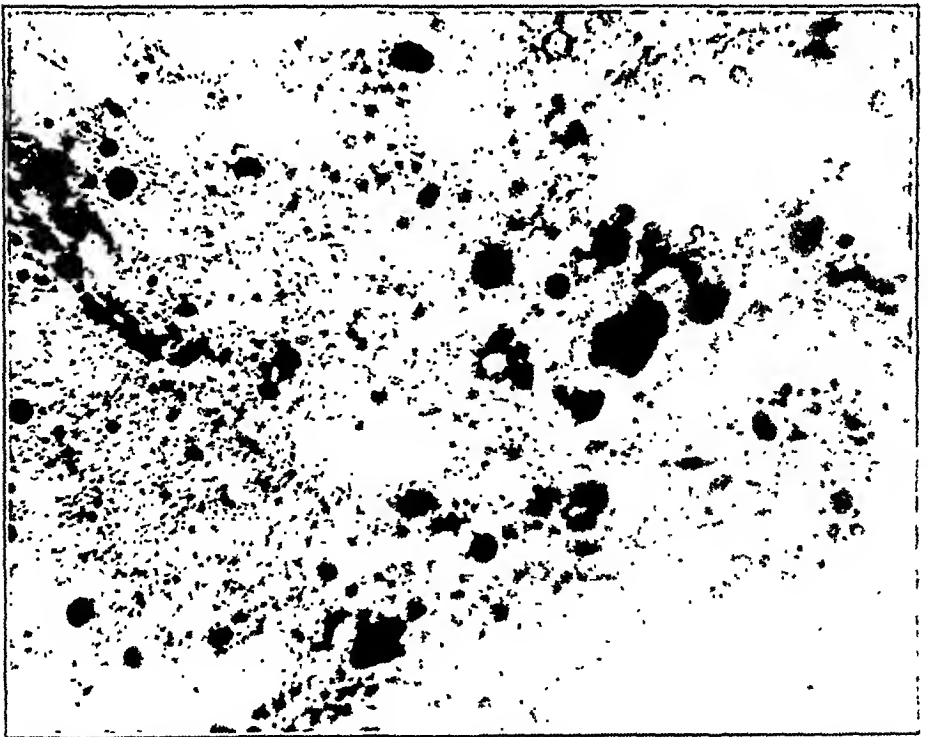


Fig. 16.—Lung of dog 46 after inhalation ether, under low power (sudan III).



We were struck by the fact that, if the human being can be compared to the dog, a man of 60 Kg. could tolerate the amazing quantity of 90 cc. of cottonseed oil, and a man of 80 Kg., a not uncommon weight, could tolerate 120 cc. Ignoring for the time the differences in viscosity and melting points between human marrow fat and cottonseed oil, we then calculated the available fat in the marrow of the femur. Later we encountered Scriba's similar calculations and identical reasoning, as summarized above, and were satisfied to find fair agreement.

We first split the femora of three skeletons. These were respectively 47.2 cm., 49.4 cm. and 48.6 cm. in length, corresponding to heights of 6 feet 3 inches, 6 feet 4 inches and 6 feet 4 inches. This calculation is

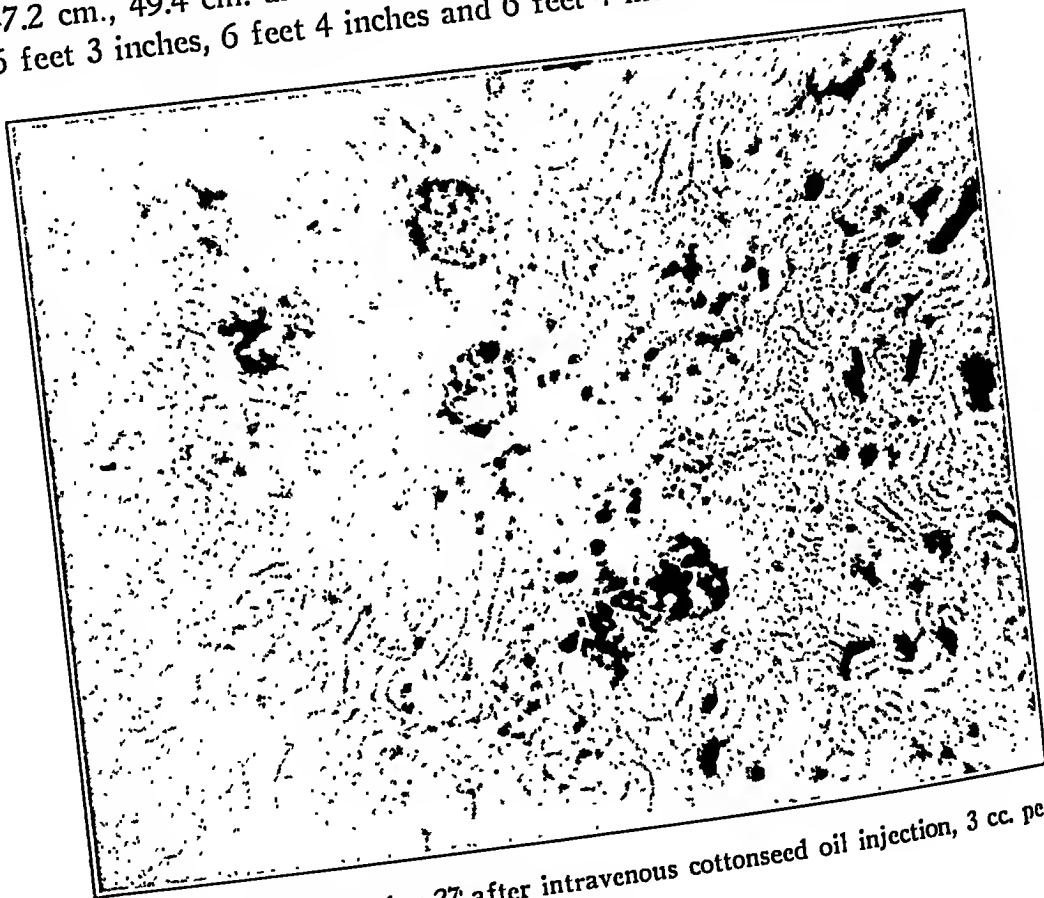


Fig. 22.—Kidney of dog 27 after intravenous cottonseed oil injection, 3 cc. per kilogram, under low power (sudan III).

based on Martin's citations<sup>31</sup> that the femur is approximately one fourth the total length of the body. We can reduce these rather excessive heights to a uniform 6 feet and still deal with persons whose weight must be at least 75 Kg. The open marrow cavities of these bones were then measured, exclusive of the definitely cancellous portions, and the capacities were calculated. The capacities of the three marrow cavities were respectively 96.2 cc., 106.7 cc. and 96.2 cc., an average of 99.7 cc.

31. Martin: *Lehrbuch der Anthropologie*, Jena, 1914, p. 254.

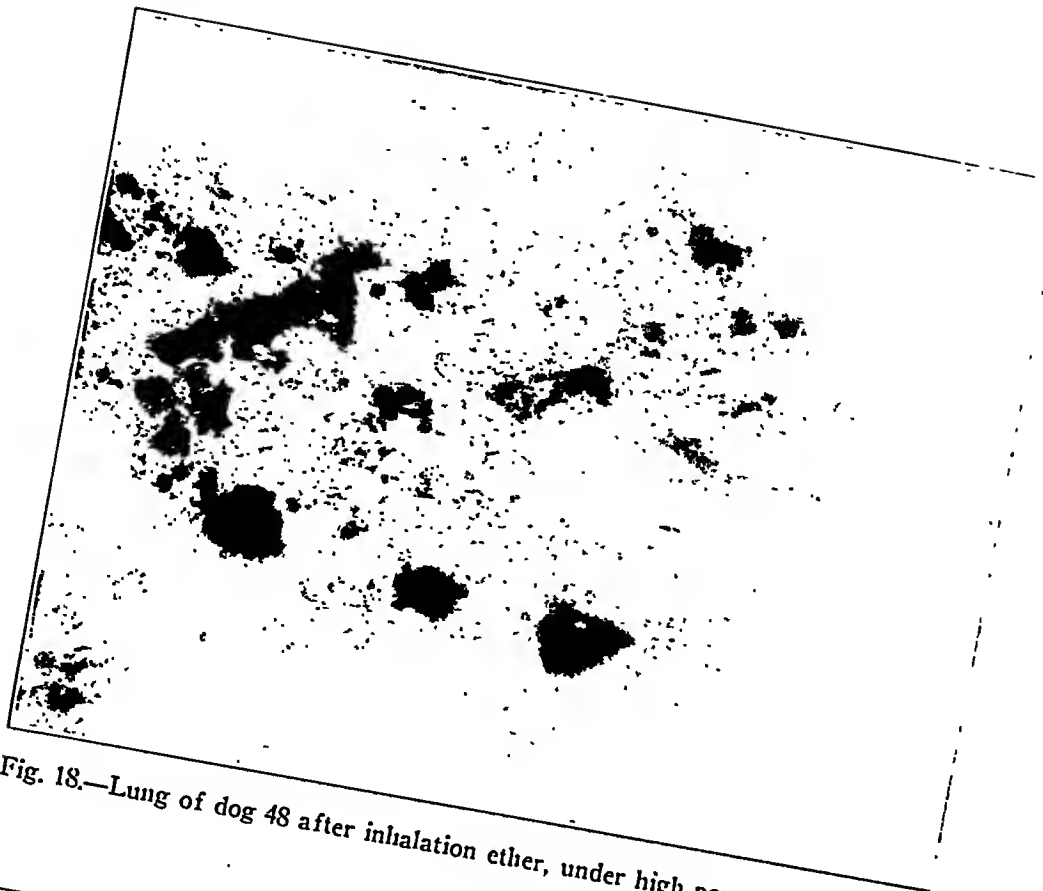


Fig. 18.—Lung of dog 48 after inhalation ether, under high power (sudan III).

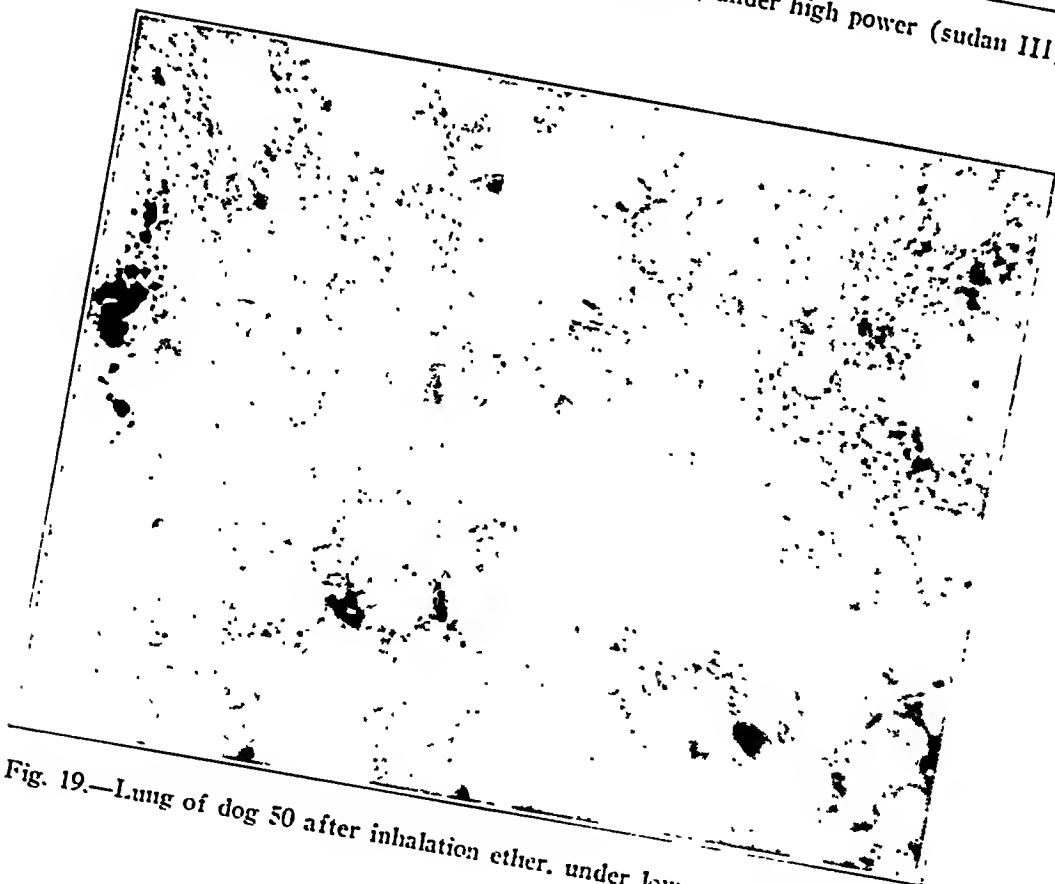


Fig. 19.—Lung of dog 50 after inhalation ether, under low power (sudan III).

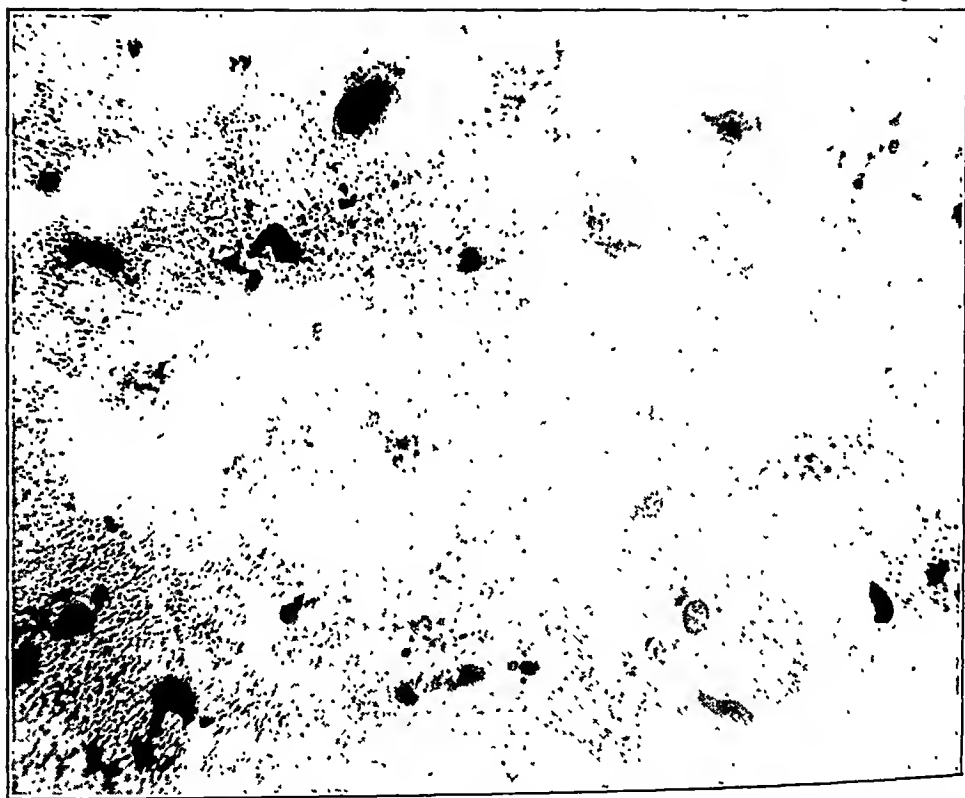


Fig. 23.—Lung of dog 30 after intravenous cottonseed oil injection, 0.8 cc. per kilogram, under low power (sudan III); the dog was killed one week after the injection.

Table 4 represents the control dogs. Seven dogs were bled to death under cocaine, used locally, or a barbituric acid derivative. Of these six were fat fed. Two of the latter showed a few emboli. As a check on the possibility that in these seven dogs fat emboli were washed out by the excessive hemorrhage that caused death, two facts can be mentioned. In the first place, in the lung capillaries of all these dogs the usual number of fat containing leukocytes could be made out. In the second place active bleeding from the carotid should have less effect in emptying the lung capillaries than passive bleeding from the pulmonary veins of the excised lung. This, we have seen, does not remove emboli. The presence of emboli in two of this series is additional evidence.

Three fat fed dogs were killed instantaneously by intracardiac injections of 20 per cent sodium cyanide solution. One dog showed many emboli; the other two showed none.

TABLE 5.—*Recapitulation*

Ether Experiments				Controls			
Embolism		No Embolism		Embolism		No Embolism	
Fat Fed				Fat Fed			
15		0		3		5	
Not Fat Fed				Not Fat Fed			
3		1		0		6	
Totals 18		1		3		11	
Percentage of Embolism = 95				Percentage of Embolism = 21			

Three dogs are included from the calcium lactate and histamine experiments as they represent other causes of death. One of these was killed by histamine without previous digestive lipemia, and one following a fat meal. The third is a fat fed dog killed by prolonged calcium lactate injection. None of these three showed fat embolism. The choice of three negative animals from a series of six for use as controls, needs no explanation. The other three dogs showed questionable embolism. This finding, in this particular series, may be the result of the injection of histamine or of calcium lactate on the basis of our *a priori* reasoning. These three dogs, therefore, are useless as controls.

One dog that had had ether anesthesia for thirty minutes the previous day for the experimental establishment of intestinal obstruction and that had died of this condition in twenty hours is included. This dog, of course, was not fat fed. No embolism occurred.

Table 5 recapitulates these controls and compares them with the consolidated experimental results. The markedly higher embolic rate in the entire series of ether dogs over the control dogs is conclusive. Ninety-five per cent of the former showed fat embolism as compared with 21 per cent of the latter.

One further comment may be made on the quantitative factors of this problem. Assuming 7 per cent of body weight to be blood, a 75 Kg. man has 5,250 cc. of blood. We have said that the blood fat normally may range as high as 2 per cent. This man then has 105 cc. of fat in his blood. If the percentage is greater, as it may be in an intense digestive lipemia or in disease, the amount of circulating fat is correspondingly increased. From this it is evident that an effective breakdown of the plasma emulsion as suggested in Part I of this paper will furnish easily as much fat for embolic lodgment as will the marrow of a broken femur.

As we state in the introduction to this part of the paper, we are basing no conclusions on the few experiments here recorded. We intend only to present the problem for future study.

3. *Fat Embolism and Shock*.—We have proved nothing in regard to fat embolism and the products of tissue disintegration. Theoretically, however, the possibility that fat embolism may intervene in the course of delayed shock, on the basis of experiments here presented, seems strong. It seems at least sufficiently strong to warrant the recommendation that no patient suffering from shock or showing symptoms from absorption of products of protein breakdown, should be given a diet of high fat content. Particularly is this true of burns, in which fat embolism has often been demonstrated.

The results of our experimentation seem to us of the greatest theoretical importance. The physical state of the fat in the blood has not received consideration from pathologists or pathologic physiologists. It seems to have fallen on a universally distributed blind spot. That this physical state has any pathologic significance has not only received no consideration but, as we have noted, has actually been denied. Our experiments represent the first proof, so far as we have been able to determine, that changes in the physical state of blood fat may have pathologic significance.

## PART II. EFFECTS OF FAT EMBOLISM

The pathogenesis of fat embolism is not the only aspect of this condition that is obscure. The effects of fat embolism, as expressed in clinical and pathologic changes, are often equally unexplained. Contradictory observations abound. There is no constant relationship between the amount of fat found at necropsy and the amount of fat disturbed by trauma. Parenthetically, it may be repeated that the results recorded in Part I may possibly be found sufficient to explain this discrepancy. Further there is no constant relationship between the amount of fat found at necropsy and the severity of symptoms. For the latter discrepancy there has never been offered even a working explanation, such as that suggested for the former. To reach an explanation, prolonged study of the quantity of embolic fat, its distribution under differing circumstances and its physical and chemical characteristics will be required. In this portion of this article we will attempt to clear the field for such a study by summarizing what evidence has already been presented. In addition, we will report a few of our tentative experiments attacking the problem, experiments that serve only to throw into bolder relief the essence of the contradictions involved.

We are not pioneers in this phase of the problem. By far the greatest amount of experimental work on fat embolism has been done by the intravascular injection of oils and the study of their effects and their fate.

Magendie (1827) was the first to recognize that fluid fat might obstruct the blood vessels. Virchow (1865) injected oil into a neck

descent disclosed the presence of sperm. Taylor<sup>266</sup> in discussing the medicolegal aspect concerning the fertility of cryptorchids enumerates a number of cases in which the procreative power of such persons has been unquestionably established. A few writers would have us believe<sup>42, 281</sup> that it is the rule for testes retained within the abdomen to be quite normal. Uffreduzzi<sup>277, 278</sup> says that 10 per cent of cryptorchid testes exhibit spermatozoa. Rawlings<sup>217</sup> states that in fifty undescended testes removed at operation twenty-seven were examined microscopically and of these ten were fairly normal and showed a definite spermatogenesis. Odiorne<sup>201</sup> and Simmons examined seventy-seven postpuberty undescended testes and all of these showed degenerative changes. They report one instance of fertility in a man of 20 when neither testis was in the scrotum. Bland-Sutton was only able to find spermatozoa once in the histologic examination of twenty-five incompletely descended testes. Lanz<sup>158</sup> saw spermatozoa once in eleven testes that failed to reach the scrotum. Griffiths<sup>112</sup> doubts the authenticity of every case in which spermatogenesis is said to have occurred in bilateral incomplete descent, and doesn't believe that the retained testis can produce spermatozoa. In practically every instance in which spermatogenesis have been demonstrated in the examination of cryptorchids the subject has been young.<sup>286</sup> So constant has this finding been that one theory as to the nature and behavior of the undescended testis depends for its explanation on this factor.

Monod and Arthaud,<sup>187</sup> on the basis of finding a fairly normal histology in the undescended testis of a man of 20 and atrophy in two men over 40, promulgated the idea that incomplete descent is compatible with fecundity in the young but that with increase in age an atrophy slowly and progressively occurs.

Two other opinions as to the condition of the incompletely descended testis have been given credence by those who have investigated this problem. Curling<sup>64</sup> held that undescended testes developed normally to puberty, then failed to undergo the changes incident to this age and remained in the prepuberty stage. Histologic study, however, demonstrates that a real degenerative process is observed in the ectopic testis with the supervention of puberty.

Hunter<sup>130</sup> believed that the aberrant position and absent spermatogenic function were both due to congenital imperfections and that "nothing can be done by art to give the testicles the stimulus of perfection which is necessary to make them assume the disposition requisite for their descent." Hunter's opinion today claims as adherents numerous supporters and investigators. Bland-Sutton<sup>22</sup> states, "A testis is retained because it is imperfect. The migratory impulse in a healthy, normal testis is irresistible"; and again, "The imperfections of an undescended testis are the cause, not the consequences of its failure

sorbed more rapidly than the vegetable oil. Again in 1920 Miller<sup>30</sup> reported rapid reabsorption of oil injected in sublethal quantities and was able, by repeated injection, to get one dog to tolerate 260 cc. in a period of five weeks time.

Paul and Windholz (1925)<sup>3</sup> have reported work on the injection of human fat into the veins of rabbits. Repeated injection in nonfatal doses resulted in a nonprotein nitrogen retention as great as that in uremia. The blood sugar fell as low as in the insulin death of rabbits and the blood lipase did not rise. The injected fat was traced throughout the organs. It gave rise to an endothelial proliferation in the lungs and an increase in leukocytes. The fat was taken up by endothelial cells and histiocytes with the formation of giant cells. Blood pigment was deposited in the spleen. There were miliary hemorrhages and softenings in the brain. There was an increase in fat in the heart muscle fibers, in the renal epithelium, and in the Kupffer cells, and there was a parenchymatous necrosis in the liver, which was free from glycogen.

To summarize the significance of this experimental work is impossible. The foregoing review only emphasizes the absence of agreement on any phase of the problem and offers no single logical explanation to unify the varying clinical and pathologic findings.

#### EXPERIMENTS

Our first experimental attack on this chaotic situation has been an attempt to establish the lethal dose of oil injected intravenously in dogs. Varying results recorded above make dependable observations obligatory. Before such observations become dependable they must be made in great number and with a variety of oils of different viscosities and melting points. So far we have used only cottonseed oil, and our experiments are few. They suggest, however, that a lethal dose can probably be determined.

Intravenous injection of sterile cottonseed oil (autoclaved) was done under aseptic precautions. The oil was injected with a syringe over a period varying from a few seconds to twenty minutes. The differences in rapidity of injection seemed to make no difference in the effects, although such a conclusion can be little more than an impression. Brief ether anesthesia was employed and the vein was exposed by a small incision which was afterward closed by a single silk suture. None of the wounds suppurated.

Table 6 shows the results of varying dosages of cottonseed oil in twelve dogs. Three dogs that received 2 cc. or more per kilogram died spontaneously within a few hours. Two dogs that received 1.7 and 1.66 cc. per kilogram, respectively, died within a few days. Six

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30. Miller: *Tr. Coll. Phys. Philadelphia* 42:25, 1920.



testes have been redeposited in the scrotum. The influence of severance of the blood vessels in the spermatic cord and ligation of the vas deferens has also been noted. Special study has been given the anatomy of the prepuberty testis.

#### DESCENT OF THE TESTIS

The abdominal position of the fetal testis was first mentioned by Haller.<sup>130</sup> Frankl<sup>98</sup> states, however, that this was also known to Galen. Hunter,<sup>130</sup> who first described the normal descent of the testis, was at a loss for a satisfactory explanation. Many of the early investigators attributed it to the action of the cremaster.<sup>270</sup> Edwards<sup>77</sup> says that the gubernaculum shortens with descent and turns about much as can the finger of a glove. Hart<sup>24</sup> speaks of the gubernaculum as a rudder. Keith\* states that the gubernaculum in drawing the peritoneum down drags the testis with it like a log on a sledge. That the gubernaculum has little or no active part in the descent of the testis becomes evident in the cases in which the testis is in the scrotum, but there is an absence of fixation<sup>270</sup> to the scrotum by the gubernaculum.

The testis develops on the inner side of the wolffian ridge in close relation with the kidney and remains intra-abdominal in position<sup>29</sup> throughout the greater portion of fetal life. Scammon<sup>232</sup> divides the transition of the testes to their scrotal position into three stages. In the sixth week of fetal life, the genital ridge extends from the sixth to the twelfth dorsal segments. During the third month, because of an atrophy of the cranial segments, the definitive testis lies in the iliac fossa. As a consequence of unequal rate of growth of structures below and above the inguinal ligament, the testis comes to lie at the future internal abdominal ring. These two phases of descent are entirely passive. Preceded by the vaginal process of peritoneum, the testis passes obliquely through the abdominal wall, reaching the external abdominal ring during the seventh or eighth month. In over 90 per cent of new-born children the testis has arrived at the bottom of the scrotum. The scrotum, a derivative of the abdominal wall, is preformed to receive the testis. At birth the upper portion of the vaginal process is obliterated,† but the lower end persists throughout life as the tunica vaginalis propria. Failure of this peritoneal tunic to obliterate in the upper portion constitutes a potential inguinal hernia. The passage of the testis through the abdominal wall is an active migration, but Scammon<sup>232</sup> states that there is no known cause adequate to account for this stage of descent.

\* Human Embryology and Morphology, New York, 1921, p. 399.

† For an excellent discussion of the obliteration of the vaginal process reference should be made to Engel,<sup>81</sup> Frankl,<sup>98, 99</sup> Lockwood,<sup>100</sup> Sachs<sup>221</sup> and Zuckerkandl.<sup>302</sup>

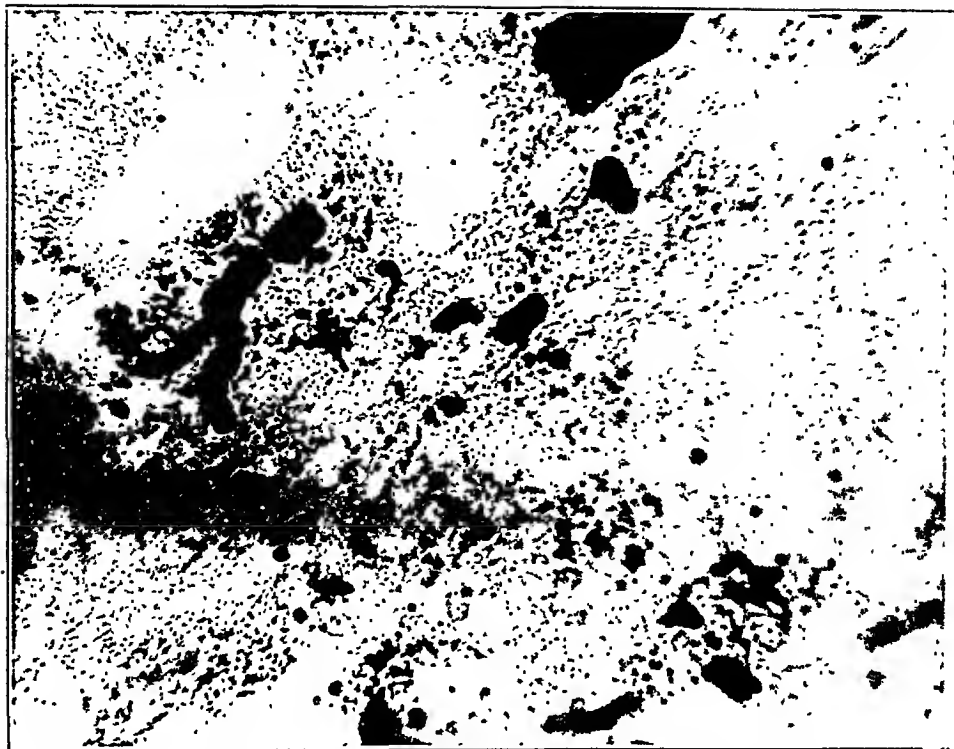


Fig. 20.—Lung of dog 27 after intravenous cottonseed oil injection, 3 cc. per kilogram, under low power (sudan III).

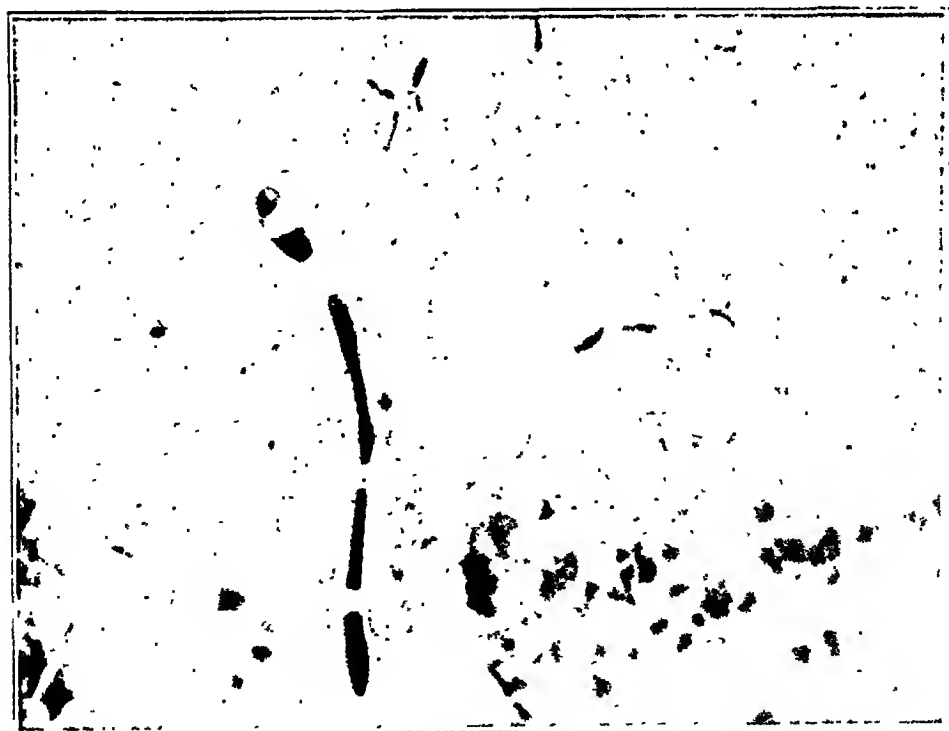


Fig. 21.—Medulla of dog 27 after intravenous cottonseed oil injection, 3 cc. per kilogram, under low power (sudan III).

plete descent\* for every thousand cases examined. Double incomplete descent<sup>188</sup> is incomparably more rare than single and right sided arrest of descent occurs more commonly than it does on the left. This is in agreement with the fact that the left testis usually descends earlier than the right.

Only rarely does the testis reach the scrotum by its own initiative if it has failed to do so at the end the first year. Neugebauer reports thirty-eight cases of late descent.<sup>128</sup> With the increasing obliquity<sup>40</sup> of the inguinal canal due to the growth of the pelvis, the possibility that the testis may migrate spontaneously to the scrotum decreases greatly. Occasionally a testis that has been in the scrotum will return to the inguinal region. This is known as "ectopie en retour."<sup>128</sup> Stefko<sup>287</sup> has recently described the finding of a high percentage of inguinal testes in starving children (27 per cent). He attributes this finding to too short a cremaster occasioned by starvation in which an unequal growth of the muscles of the abdominal wall occurs.

#### CAUSE OF FAILURE OF THE TESTIS TO DESCEND

Undoubtedly a number of factors may operate to bring about incomplete descent of the testis. Eccles<sup>75</sup> classifies the conditions that may be causative as follows:

1. Conditions associated with the mesorchium.
2. Those associated with the testis and its component parts.
3. Conditions associated with the gubernaculum.
4. Conditions associated with the cremaster.
5. Those associated with the route along which the testis must pass.

In by far the majority of cases of inguinal retention, however, separation of the spermatic cord from the processus tunica vaginalis testis suffices to mobilize the gland so that it may be placed in the bottom of the scrotum.<sup>25, 45, 171, 212</sup> Bevan<sup>16</sup> states that separation of the peritoneum from the vas deferens and spermatic vessels, if carried from 2 to 3 inches (5 to 7.6 cm.) within the abdominal cavity and combined with removal of all the coverings of the cord, so that the testis hangs suspended by the vas and vessels alone, will so mobilize the testis that in many instances it may be placed on the thigh several inches below the inguinal ligament. Bevan<sup>19</sup> says that in only 10 per cent of cases has it been necessary to section the vessels in the pampiniform plexus in order to bring the testis into the scrotum. Büdinger<sup>38, 39</sup> states that the vessels are always short and cites the relation that obtains in

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\* This figure includes anorchism and monorchism. Absence of the testis is an exceedingly rare anomaly and it is scarcely possible during life to obtain reliable proof concerning its existence. Jacobsen<sup>284</sup> says that Gruber in 1868 could compile only twenty-three cases of unilateral anorchism and seven of the bilateral variety, all having been verified by necropsy.

We then cut measured segments from two freshly amputated femora and calculated the capacity of the marrow cavities. The fat in the marrow was melted out, measured, and 10 per cent added for possible error. From these two calculations we found that in the one instance 50 per cent of the marrow cavity content was fat and in the other instance, 63 per cent.

Applying the larger of these figures, which more nearly approaches Scriba's measurements, to the average complete marrow capacity as calculated above, we find that the marrow cavity of the femur of a 75 Kg. person contains approximately 65 cc. of fat. This corresponds to 0.86 cc. per kilogram.

The significance of these calculations now becomes apparent. If the difference in effect between marrow fat and cottonseed oil is not great, and if man can tolerate oil as easily as the dog, then one should be able to pour into the veins all the fat from the marrow of a single femur without causing symptoms.

The fundamental contradiction is clearly presented by this example. Several solutions, any or all of which may be effective, can be proposed:

1. Is there a difference in susceptibility to fat between dog and man?
2. Is the difference between cottonseed oil and marrow fat sufficient to make so great a difference in threshold value?
3. Is there an additional source of the fat in traumatic fat embolism, other than the depot fat? (Our results in Part I suggest that this may be so.)
4. Do symptoms depend on some law of distribution of fat emboli, dependent, perhaps, in differences in the architecture of the vascular tree between dog and man, such as the absence in the dog of the internal carotid artery?
5. Do symptoms depend on chance distribution of emboli to vital centers?
6. Has it been established without question that symptoms ascribed to fat embolism are really due to that cause, and not to other disturbances of physiologic balance?

In regard to this last query we report an interesting observation. None of the dogs that received intravenous injections of cottonseed oil developed pulmonary edema that could be detected clinically, even when as much as 3 cc. per kilogram was given. The high proportion of dogs, however, showed the gross and microscopic lung changes of pulmonary edema. In the classical clinical description of fat embolism, pulmonary edema as a symptom is given much weight.

of the tubule and scattered between the Sertoli cells are the spermatogonia, the progenitors of the adult male sex cell. In the prepuberty testis, the Sertoli cells and the spermatogonia are the only cells lining the seminiferous tubules. In the mature testis, the spermatogonia are small round elements with nuclei rich in chromatin. By growth the spermatogone becomes a spermatocyte of the first order. These divide and form two secondary spermatocytes whose division gives rise to the spermatids from which the spermatozoa takes origin.

In the intertubular spaces there are groups of cordlike masses, the interstitial cells.\* These are rounded polygonal elements with small eccentric nuclei. Scattered in the finely granular cytoplasm may be found pigment particles or crystalloid bodies<sup>211</sup> in the form of minute rods or needles.

The main artery of the testis is the internal spermatic which takes origin from the abdominal aorta. In addition it is also supplied by the deferential and external spermatic arteries which establish anastomoses with the internal spermatic. The testicular branches enter the mediastinum and break up into superficial and deep twigs that follow the tunica albuginea and the septums, respectively. The latter follow the tracts of intertubular connective tissue and ultimately form rich capillary networks enclosing the seminiferous tubules outside the basement membrane. The veins arise in these networks and emerge at the mediastinum and together with the veins from the caput epididymidis ascend in the spermatic cord in the anterior part of the pampiniform plexus. The veins from the body and tail of the epididymis unite into a smaller group that ascend in the posterior part of the plexus.

The lymphatics of the testis follow the course of the veins and drain into the lumbar lymph nodes. The nerves of the testis are chiefly sympathetic fibers that follow the course of the internal spermatic artery.

The histology of the immature testis and the blood supply of the organ will be dealt with more fully later.

The retained testis of the adult when compared with its normally descended fellow, though preserving the contour of the normal organ, is of much smaller proportions. But apart from this disproportion in size the gross anatomy of the normal organ is preserved.<sup>91</sup> Occasionally the body and tail of the epididymis remain separated from the testis by the mesorchium.<sup>39, 140</sup>

When examined microscopically, however, a remarkable difference in structure is at once apparent. The singular disappearance of the germinal epithelium from the seminiferous tubules is most striking.

\* Odiorne and Simmons<sup>229</sup> and Coley<sup>49</sup> state that there are no interstitial cells in the normal adult testis. Winiwarter,<sup>203</sup> however, finds them present and Benoit<sup>23, 24, 25</sup> states that failure to observe them is due to lack of proper tissue fixation.

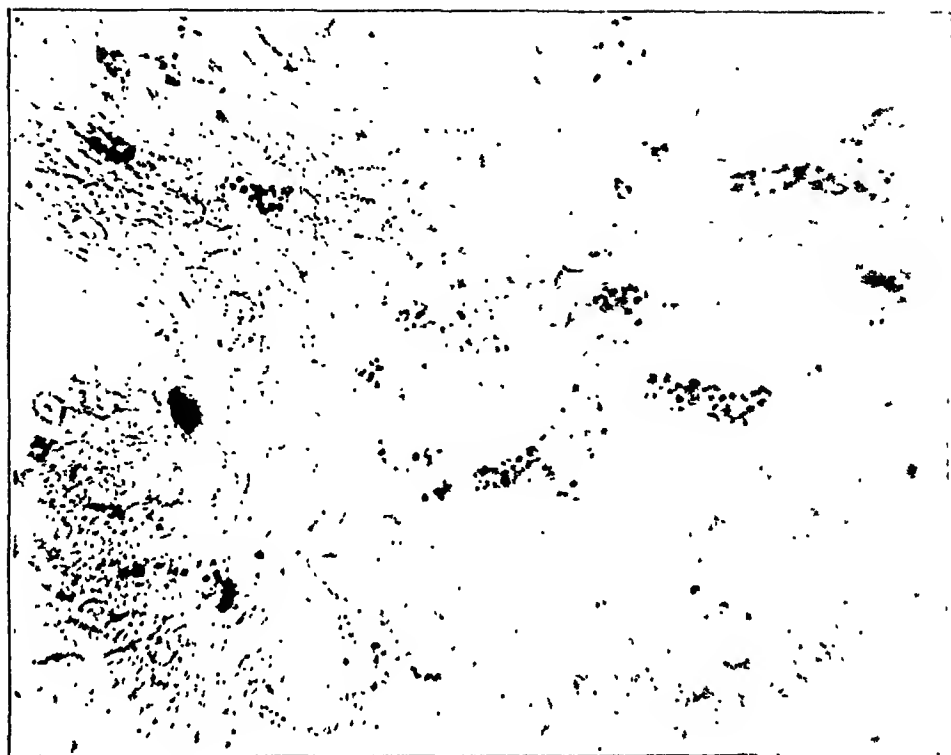


Fig. 24.—Kidney of dog 30 after intravenous cottonseed oil injection, 0.8 cc per kilogram, under low power (sudan III) : the dog was killed one week after the injection.

Scudder<sup>242</sup> compiled thirty-two cases of torsion of the pedicle of the testis. Forty-seven per cent of these occurred in undescended testes.

*Malignancy.*—Nearly all who have written on the subject of malignancy in the testis are agreed that the incompletely descended organ is more likely to become malignant than the scrotal testis. Malignancy of the testis is a rare disease.<sup>21, 237</sup> In 1922 Tanner<sup>265</sup> stated that only about 600 cases had been reported in the literature. Of 452 cases compiled by Cunningham,<sup>63</sup> 412 had occurred in the normally descended testis. Malignancy in this series therefore was 10.3 times more frequent in the scrotal than in the undescended testis. When, however, allowance is made for the fact that only one testis in 500 is undescended, it is apparent that in Cunningham's<sup>63</sup> series, at least, the undescended testis is fifty times more likely to malignant degeneration than is the normally descended testis.

Tanner<sup>265</sup> believes that the testis retained within the abdomen is less likely to become malignant than is the normally descended testis. Bulkley<sup>41</sup> states that about one testis in seventy-five retained within the abdomen will become malignant, and that one out of every four malignancies in undescended testes is found in the abdomen. Several believe that the testis within the abdominal cavity enjoys an immunity from malignancy and that when an inguinal testis cannot be placed in the scrotum that it can with safety be placed in the abdominal cavity behind the peritoneum.<sup>128, 238</sup> A few writers state that this is the operation of choice in the treatment of undescended testes,<sup>150, 281</sup> and that an imperfectly descended organ is as likely to function there as in the scrotum. Uffreduzzi<sup>278</sup> and Keyes and MacKenzie<sup>142</sup> state that the abdominal testis is more likely to become malignant than the testis retained in the inguinal region. Malignancy has never been observed in a perineal testis.<sup>144</sup>

No greater diversity of opinion probably exists concerning anything in medicine than the question of malignancy in the undescended testis.

The opinion prevalent today that the abdominal testis is less prone to become malignant than an inguinal testis or one normally situated I believe to be but a heritage from earlier literature.<sup>84, 137, 256</sup> In 1893 Farwick<sup>84</sup> could find only three cases of malignancy in the testes retained within the abdomen and seventy-seven in inguinally retained testes. In 1901 Kaepelin<sup>137</sup> could find only six malignant abdominal testes. Bulkley<sup>41</sup> in 1913 reported fifty-nine cases of malignancy in the abdominally retained testes. Cunningham<sup>63</sup> in 1921 stated that three had been reported since the appearance of Bulkley's paper. I have observed two cases of malignancy in the abdominal testis. Malignancy of the abdominally retained testis in the male hermaphrodite is not infrequent. Zacharias<sup>300</sup> mentions thirteen cases, two of which were bilateral.

# THE UNDESCENDED TESTIS

AN EXPERIMENTAL AND CLINICAL STUDY \*

OWEN H. WANGENSTEEN, M.D.

MINNEAPOLIS

It is now generally believed that the undescended testis is usually incapable of a continued production of spermatozoa. Hunter,<sup>22, 23</sup> who first described the normal descent of the testis, stated that failure of the testis to reach the scrotum is due to its initial imperfection. Most European investigators hold to this opinion. But operations are continually being performed on the undescended testis in the hope that with transference to the scrotum that spermatogenesis will occur. If the development of the testis is not altered by transition to the scrotum, only the belief that the danger of malignancy is lessened or that the patient is more pleased with his testis in its usual habitat would justify operative interference in the absence of pain or other complicating factor. A decision as to whether the testis is ab ovo deficient or whether its abnormal situation is responsible for its lack of development is therefore of paramount importance in the rational treatment of the undescended testis.

Orchidopexy is an old procedure and it would seem that the examination alone of those cases in which the operation has been done for failure of both testes to descend would determine whether or not an undescended testis would develop normally if placed in the scrotum. Records of results are numerous, as concerns the position of the transplanted organ, and many observers<sup>16, 24</sup> record an increase in size after scrotal fixation. But reports concerning examination of the semen when the operation has been done for double incomplete descent are unfortunately few, so few in fact that it could with just cause be claimed that these are merely examples of those rare instances in which a temporary spermatogenesis occurs in cryptorchids.

A sufficient number of such cases have now been recorded that one cannot deny that spermatogenesis<sup>25</sup> may occur in cryptorchids. Michal<sup>25</sup> in 1887 was able to compile fifty cases in which histological examination of the removed organ or semen examinations in double inguinal

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The relative frequency of malignancy in the undescended as compared with the normally descended organ is best accounted for in Ewing's explanation of the mode of origin of malignant testicular tumors.

Prophylactic removal of an inguinal testis because of the danger of malignancy is scarcely warranted. Such a procedure has not been applied to other organs in which malignancy is manifoldly more common.

Several instances have been reported in which tumors have occurred in the normally descended testis while the same patient carried one in which only partial descent had occurred. Howard<sup>129</sup> records the instance of a man of 37 the subject of a carcinoma of the testis. At 7 his testis was in the scrotum; as a result of trauma dislodgement occurred into the inguinal region. The converse has also been noted. Cunningham<sup>63</sup> reports the case of a man of 30 the subject of a teratomatous testis. At 25 this testis had been in the inguinal region and at that time was placed in the scrotum. Coley<sup>51</sup> reports an instance in which malignancy of the testis followed closely on replacing the testis in the scrotum. Tyrell<sup>276</sup> mentions the case of a man whose left testis descended into the scrotum spontaneously at 20. Twenty-five years later, at 45 years, a sarcoma developed in this testis. Marlier<sup>175</sup> mentions such an instance in a man whose left testis first descended into the scrotum at 16; at 38 the testis was the seat of a carcinoma. Romiti<sup>225</sup> relates the history of a man of 37 who developed a malignancy in a testis once resident in the scrotum that eleven years previously was placed in the abdomen in order to cure a large inguinal hernia.

Orchidopexy therefore does not diminish the possibility of a malignancy developing in the testis with reposition of the organ into the scrotum.

#### EXPERIMENTAL INVESTIGATION

All experiments were done on dogs (a few early experiments not recorded were done on guinea-pigs and rabbits) under usual aseptic technic. Ether was used to obtain anesthesia. Fine linen sutures were used throughout. The experiments will be tabulated according to type of procedure instead of in chronological sequence. The examination of the undescended testes and the testes removed in the course of operations for the cure of hernia and hydrocele, and those obtained from persons dying of acute febrile and chronic debilitating diseases will be recorded following tabulation of the procedures on dogs. Formaldehyde fixation (10 per cent) of tissue and hematoxylin and eosin stains were used. All tissue was embedded in paraffin and the sections were cut from 8 to 10 microns in thickness.

to reach its goal in the scrotum. . . . Surgical efforts to preserve a retained or a partially descended testis may be described as supererogation." At a recent meeting of the Royal Society of Medicine in London, Bland-Sutton<sup>24</sup> reiterated his previous stand and said that "the notion that the functional imperfection of a retained testis is due to its nondescent is false." Eccles<sup>25</sup> at the same time said that it was wrong to speak of atrophy and that an undescended testis is underdeveloped. Finotti<sup>26</sup> also shares this opinion. Uffreduzzi<sup>27</sup> describes nondescent as a local expression of infantilism. Recent investigations on the continent seem to bear out Hunter's theory. Staemmler<sup>28</sup> believes that a hypoplasia of the spermatic arteries is the cause of lack of development and also prevents descent. Schinz and Slotopolsky<sup>29</sup> state that cryptorchidism is essentially a hypoplastic process and that this hypoplasia is only a part of a general developmental disturbance "vitium primae formationis."

It has, however, long been felt by many that given the advantage of the natural environment that the scrotum affords an incompletely descended testis would develop normally and that the success or failure of the scrotal fixation would be a dominant factor in determining the future possibilities of the imperfectly descended organ. The almost universal practice of orchidopexy therefore signifies that many still cling to the belief that failure to reach the scrotum accounts for the aspermatic condition of the undescended testis.

It has been my object in this study to investigate the merits of these two controversial opinions. If the incompletely descended testis owes its imperfect development to its failure to descend, a successful orchidopexy would rectify the condition and stamp the operation as being of material and functional benefit. Failure of the germinal epithelium to develop would indicate that the object of the procedure is only cosmetic. These two diametrically opposed ideas cannot be compromised. Does transition to the scrotum enable an imperfectly descended testis to develop normally or is it *ab initio* imperfect and incapable of mature growth?

#### MODE OF INVESTIGATION

In the study of this problem several testes that failed to reach the scrotum and were removed in the course of operations for hernia in adults have been examined. Normally descended testes removed in the radical cure of large hernias and hydroceles have also been submitted to examination. Testes of young boys and adults have been placed in the peritoneal cavity and the inguinal region to determine the effect on the organ noted. After having been allowed to remain in the peritoneal cavity or inguinal region for a given period, a number of

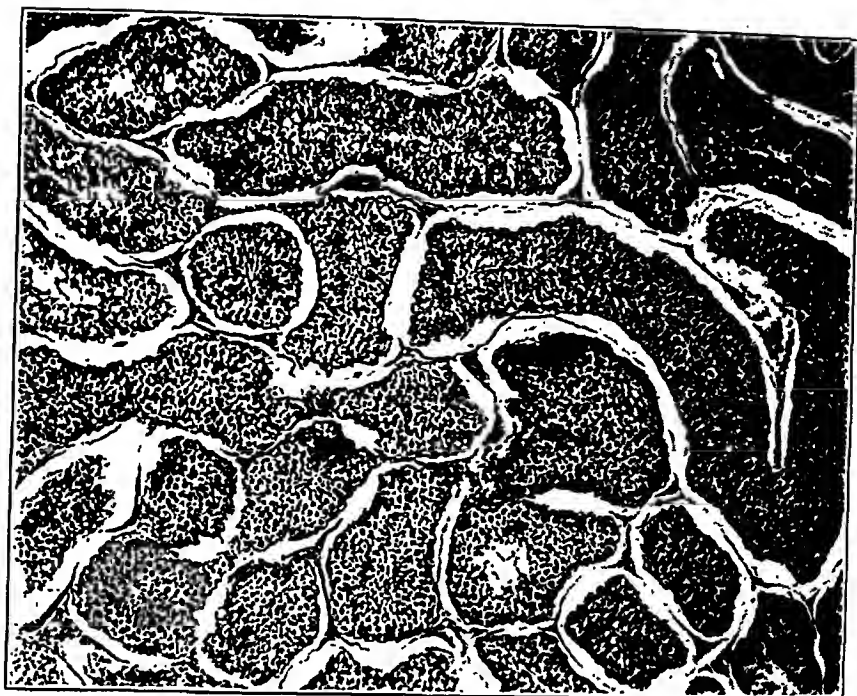


Fig. 1 (experiment 3).—Left testis of adult dog; control in scrotum showing the normal condition in the mature testis in which all the mature germinal cells are present ( $\times 100$ ).

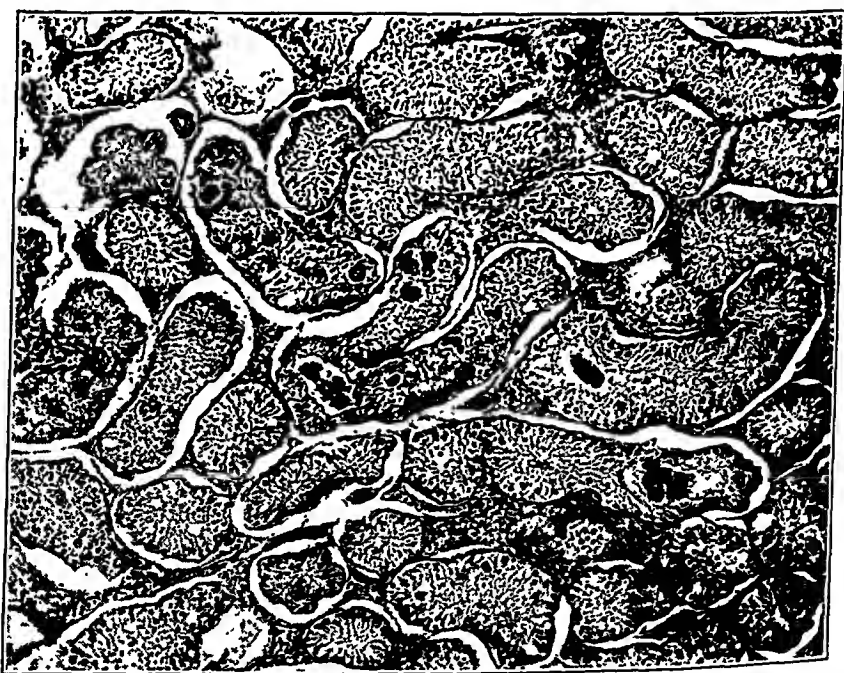


Fig. 2.—Right testis of same dog as shown in figure 1 after having been in the peritoneal cavity for five days; marked destruction of the germinal epithelium; formation of multinucleated cells; Sertoli cells still in fair state of preservation; interstitium normal ( $\times 100$ ).



Microscopically, the testes were those of a normal young pup. There was no elaboration of the germinal epithelium above the spermatogonia. In some of the lumina of the tubules of the right testis, which was placed in the peritoneal cavity, there were large cells with acidophilic cytoplasm. There were no multinucleated cells and no débris in the tubules. (These cells probably represent the earliest degenerative phase in the testes of the young)

EXPERIMENT 9.—Sept. 21, 1923; a small young dog, aged about 3 months.

Both testes were placed in the peritoneal cavity.

November 19, fifty-nine days later, the dog was killed. The left testis was adherent to the abdominal wall; the right was free.

Microscopically, the testis was that of a normal pup. There was no evidence of degenerative phenomena. There were numerous spermatogonia. The germinal epithelium was from two to three rows in thickness. There was no débris in the lumina. Some peritubular edema was noted (shrinking in fixation?).

EXPERIMENT 10.—Sept. 22, 1923; a young dog, aged about 5 months:

Both testes were placed in the peritoneal cavity.

October 5, thirteen days later, the dog was found dead.

Both testes were free in the peritoneal cavity. Microscopically, both these testes showed the picture mentioned in experiment 8, viz., large mononucleated cells with a reddish cytoplasm within the lumina. There were no multinucleated cells and no débris.

EXPERIMENT 11.—Sept. 24, 1923; a 5 months old dog.

Both testes were placed in the peritoneal cavity.

October 5, eleven days later, the dog was killed. The right testis was free in the peritoneal cavity; the left was ensheathed in adhesions of omentum. The epididymis was swollen. The surface of the testis was hemorrhagic. The vessels were slightly twisted.

Microscopically, the right was a normal pup's testis. No degenerative changes were present. The left had many tubules hyaline in appearance. Loss of ability of the cells in the tubules to take a stain was apparent in several areas. There were many polymorphonuclear cells in the interstitium. (This testis apparently was the victim of torsion of its vessels.)

EXPERIMENT 12.—Sept. 29, 1923; a small pup, aged about 4 months.

Both testes were placed in the peritoneal cavity.

December 1, sixty-three days later, the dog died. The right testis was slightly adherent to the greater omentum at the anterior abdominal wall. The left testis was free. There was no torsion of the vessels.

Microscopically, there were large mononucleated cells with acidophilic cytoplasm in the lumina (as in experiments 8 and 10). The outline of the tubules was well preserved. No other degenerative changes were present.

EXPERIMENT 13.—Oct. 11, 1923; a pup, aged 3 months.

Both testes were placed in the peritoneal cavity.

December 19, sixty-nine days later, the dog was killed. Both testes were free in the peritoneal cavity. There was no vessel constriction. The histologic report\* was the same as in experiment 12, 8 and 10; that is, there were large

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\* Many of these young dogs operated on in the later part of 1923 had mange. Though the testis of the young is not as sensitive to the effect of debilitating diseases as is the testis of the adult, nevertheless in the testis immediately before puberty slight degenerative changes are noted. Not unlikely, these are the result of the mange and malnutrition as much as the effect of transplantation. mononucleated cells with the tubule histologically otherwise normal.









necrobiosis from the lumina only the Sertoli cells remain within the tubules. Many of these have altered nuclei with only a scant amount of chromatin and lie on the membrana propria of the seminiferous tubules as empty irregular sacs.

None of these degenerative changes were observed in the interstitium. On the contrary, the interstitial cells appear prominent and increased in number. An actual hyperplasia seems to have occurred. Oslund<sup>203</sup> believes, however, that this increase is probably relative because of the disappearance of the germinal epithelium.

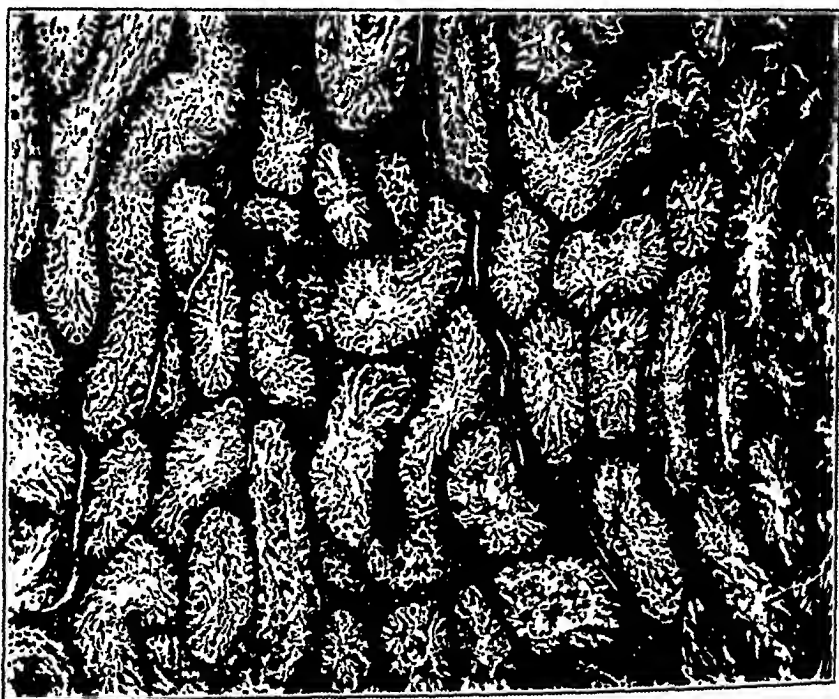


Fig. 6 (experiment 21).—Right testis of adult dog mobilized as for transplantation into the peritoneal cavity but immediately redeposited in the scrotum; removed twenty-five days later; the damage incident to the manipulation is apparent ( $\times 100$ ).

#### EXPERIMENTS TO DETERMINE THE REACTION OF THE TESTIS TO INJURY

##### SERIES II

EXPERIMENT 21.—Aug. 4, 1923; an adult dog.

Both testes were freed from the scrotum and prepared as for transplantation into the peritoneal cavity, but were immediately replaced in the scrotum.

August 29, twenty-five days later, the dog died without apparent cause. The wounds were well healed. The testes were slightly smaller than at operation. Microscopically, there was marked destruction of the germinal epithelium, most of which had disappeared. A few spermatogonia still remained. In the lumina of the tubules numerous giant cells and debris were present. In many tubules the

Bland-Sutton<sup>24</sup> says that thirty-five have been reported. Romiti<sup>225</sup> reports the case of a man at thirty-seven who had a malignant abdominal testis. Eleven years previously during the course of a hernia operation the testis which had previously been scrotal in position was placed in the retroperitoneal region in order to better treat the hernia.

When it is recalled that malignancy is a rare disease in the testis, that an undescended testis is also infrequent, and that abdominal retention of the testis occurs with considerable less frequency than does inguinal retention, it must be conceded that an abdominal situation of the testis is not a protection against malignancy.

It has long been felt that the exposed position<sup>70, 245</sup> of the inguinal testis to trauma renders it susceptible to malignant change. The relative frequency of torsion in the inguinal testis has been pointed out. Kahlden<sup>138</sup> believes that the contraction of the abdominal muscles over the testis in the inguinal region, as occurs with coughing, lifting, etc., is responsible for the frequency with which malignancy is observed in the inguinal testis. Landau states that the contraction of the abdominal muscles over an inguinal testis could exert but little pressure on the gland.<sup>277</sup>

Coley<sup>52</sup> believes that trauma is a factor in one third of the cases of malignancy of the testis. Chevassu<sup>47</sup> states that traumatism favors the growth of a tumor but believes that trauma as a causative factor in testicular malignancies has been over rated.

In the undescended testis, the anatomic peculiarities\* observed are the disappearance of the germinal epithelium and a hyperplasia of the interstitial cells. It has been suggested that the relative frequency of malignancy in undescended testes takes origin in these cells,<sup>62, 29</sup> but sarcoma of the interstitial cells<sup>83</sup> is a very rare tumor. A benign tumor † arising in the interstitial cells is not uncommon.

Wilms<sup>202</sup> stated that the complex malignant tumors of the testis contained all three germinal layers and were best considered as teratomas. Ewing<sup>82</sup> from a careful study of nineteen cases and an examination of the literature on the subject states that "the great majority or possibly all of these tumors are of teratomatous origin." Ewing<sup>82</sup> had several thousand serial sections made of embryonic testes through the corpus Highmori and rete testis. Several islands of chromaffin tissue and two misplaced groups of squamous epithelium were found. Ewing concludes "that teratoma testis arises from sex cells in the neighborhood of the rete, whose normal development into spermatogonia has been suppressed but whose potencies remain intact or ready to express themselves in the various forms of simple or complex teratomata."

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\* It has erroneously been maintained that an ectopic perineal testis<sup>25, 27</sup> is histologically normal.

† It is said to occur frequently in old dogs.<sup>28</sup>

TRANSFERENCE OF THE TESTIS TO THE PERITONEAL CAVITY OR  
 INGUINAL REGION WITH REPLACEMENT IN THE SCROTUM  
 AT A LATER DATE, WHEN DEGENERATIVE CHANGES  
 HAVE OCCURRED IN THE TRANSPLANTED ORGAN

SERIES III

EXPERIMENT 26.—July 8, 1923; an adult dog.

Both testes were transplanted into the inguinal region.

August 20, forty-two days later, the right testis was redeposited in the scrotum. The left testis was removed.

October 29, seventy-one days later, the right testis was removed. Microscopically, the left testis showed a typical transplant testis in which the germinal epithelium had practically disappeared. The products of necrobiosis had been



Fig. 7 (experiment 27).—Right testis of dog after having been in the peritoneal cavity for thirty-seven days ( $\times 100$ ).

removed. In the right testis definite attempt had been made to regenerate the germinal epithelium. In areas all the adult sex cells were present, including a few spermatozoa.

In those tubules in which the spermatogonia had all disappeared, no regeneration was apparent.

EXPERIMENT 27.—Feb. 18, 1925; a large adult bulldog.

Both testes were placed in the peritoneal cavity.

March 27, thirty-seven days later, the right testis was removed. The left testis was replaced in the scrotum. The spermatic cord was not under tension. The testis was sutured to the bottom of the scrotum, and the tunica vaginalis testis covering the testis was included in the sutures that united the inner layer of the scrotum.

November 4, 190 days later, the left testis, which was of good size, was removed. It was movable in the scrotum. Microscopically, the right testis was a

TRANSPLANTATION OF TESTES OF MATURE AND YOUNG DOGS  
INTO THE ABDOMINAL AND INGUINAL REGION

## SERIES 1

EXPERIMENT 1.—July 1, 1923, large adult dog.

Abdominal reposition was made of both testes through oblique incisions in both inguinal regions. The spermatic cord was freed and the internal ring enlarged on both sides. The gubernacula were severed, the peritoneal cavity was opened on both sides and the testes were pushed into the abdomen. On the left, the tunica vaginalis testis was removed; on the right side it was left intact. The wounds were closed in layers.

After the lapse of two months, this dog was kept with two adult female dogs for a considerable length of time without impregnating them.

December 28, 180 days later, castration was done. The wounds had healed well. The left testis was free in the peritoneal cavity; the right was ensheathed in omental adhesions. There was no interference with the vascular supply of either testis. Grossly both testes were markedly reduced in size. The tunica albuginea was thickened. Microscopically there was total loss of the germinal epithelium. Only Sertoli cells remained within the seminiferous tubules. In some of these, the nuclei were small and the cells gave the appearance of empty sacs. Many of the tubules were distorted. The interstitial cells appeared quite prominent.

EXPERIMENT 2.—July 5, 1923; an adult dog.

Abdominal reposition was made of both testes through inguinal incisions. The tunica vaginalis testis was left intact on both sides.

July 11, six days later, the dog was killed. There was a small hematoma in the right wound; the left was well healed. The right testis was free in the peritoneal cavity at the brim of the pelvis. The left testis was free except for slight attachment to the great omentum. Both testes were somewhat smaller than at operation.

Microscopically, there was definite loss of the germinal epithelium within the tubules. Numerous giant cells and debris occupied the lumina of the tubules. The interstitium was normal.

EXPERIMENT 3.—July 9, 1923; an adult dog.

Abdominal reposition was made of the right testis. The left testis was not touched.

July 14, five days later, castration was done. There was the same picture as in dog 2. The left testis showed normal spermatogenesis.

EXPERIMENT 4.—July 27, 1923; an adult dog.

Abdominal reposition was made of both testes through inguinal incisions.

August 6, ten days later, castration was done. The loss of germinal epithelium was a little more definite than in dog 2. Giant cells and necrobiotic changes were evident in all tubules. In many most of the sexual cells had disappeared. There was considerable peritubular edema.

EXPERIMENT 5.—Feb. 20, 1925; an adult dog.

Both testes were put into the peritoneal cavity through inguinal incisions.

April 13, fifty-two days later, castration was done. The testes were reduced in size; the tunica albuginea was thickened; the germinal epithelium was gone. Only a single row of Sertoli cells remained in the tubules. No products of necrobiosis were present. The interstitium was normal.

September 10, twenty-one days later, the left testis was removed; the right testis was replaced in the scrotum.

December 15, ninety-six days later, the right testis was removed; a large testis was movable in a pendant scrotum.

Microscopically, there was almost complete disappearance of most of the germinal cells in the left testis. Only a few spermatogonia remained. In the right the normal condition had been reestablished in most of the tubules. In some there were no adult germinal cells.

EXPERIMENT 36.—Sept. 1, 1925; a medium sized adult dog.

The right testis was transplanted into the inguinal area. The left testis was allowed to remain in the scrotum.

September 17, sixteen days later, the right testis was replaced in the scrotum.



Fig. 11 (experiment 32).—Right testis of same dog as shown in figure 10, also in the inguinal region for thirteen days but replaced in the scrotum (when the left testis was removed) and allowed to remain in the scrotum for sixty-three days. Regeneration in a much shorter time is possible when the testis does not remain too long outside the scrotum.

December 18, ninety-two days later, both testes were removed. The testes were about of the same size, movable in the pendant scrotum.

Microscopically, the left was normal and there was elaboration of all the adult germinal cells in nearly all the tubules of the right.

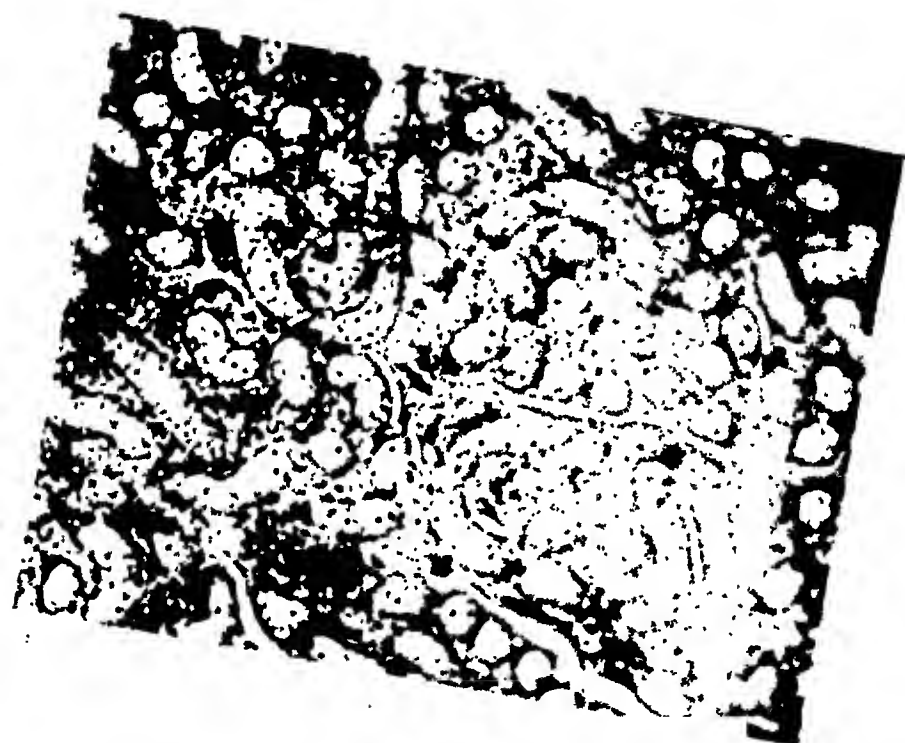
EXPERIMENT 37.—Sept. 3, 1925: a large adult dog.

The right testis was transplanted into the inguinal region. The left was not touched.

September 16, thirteen days later, the right testis was replaced in the scrotum.

December 18, ninety-three days later, both testes were removed. The left was somewhat larger than the right.

Microscopically, the left was normal: marked regeneration was noted in most of the tubules of the right. A few showed little or no regeneration.



December 28, 108 days later, the testes were small. The dog had increased in weight. Microscopically, the picture was the same as in experiment 44. The epididymis was normal. Only fibrous tissue and deposits of a brownish pigment persisted in the testis.

EXPERIMENT 46.—Sept. 17, 1923; an adult dog.

The vessels on both sides were ligated and severed, leaving the vas deferens and its accompanying vessels intact.

October 5, eighteen days later, both testes were large and injected. Microscopically, the contour of the tubules was still preserved. The lumina of the tubules was occupied by red blood cells. Most of the germinal cells had disappeared. There was marked edema in the interstitium. Most of the cells stained poorly.

EXPERIMENT 47.—Dec. 27, 1923; an adult dog.

The internal spermatic artery was ligated on both sides.

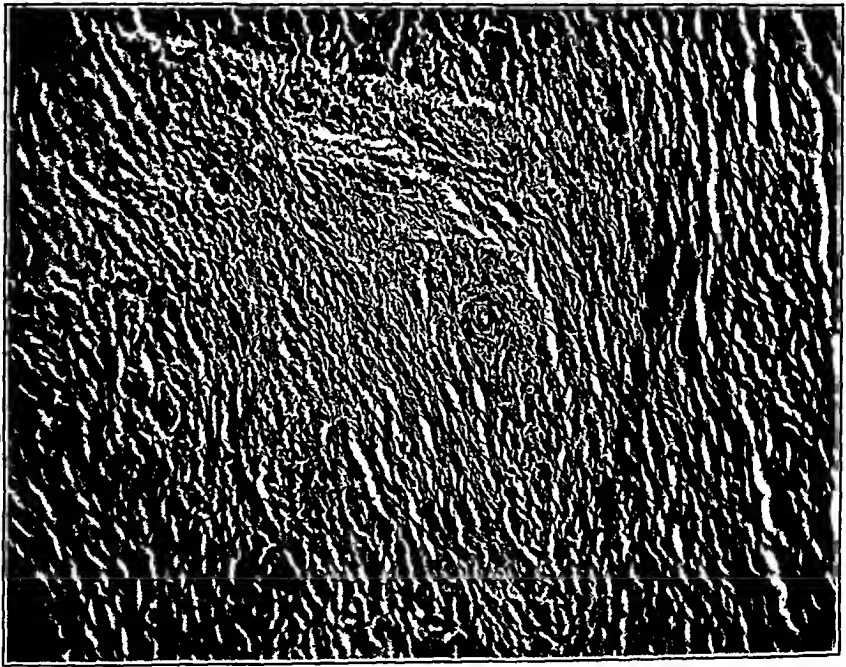


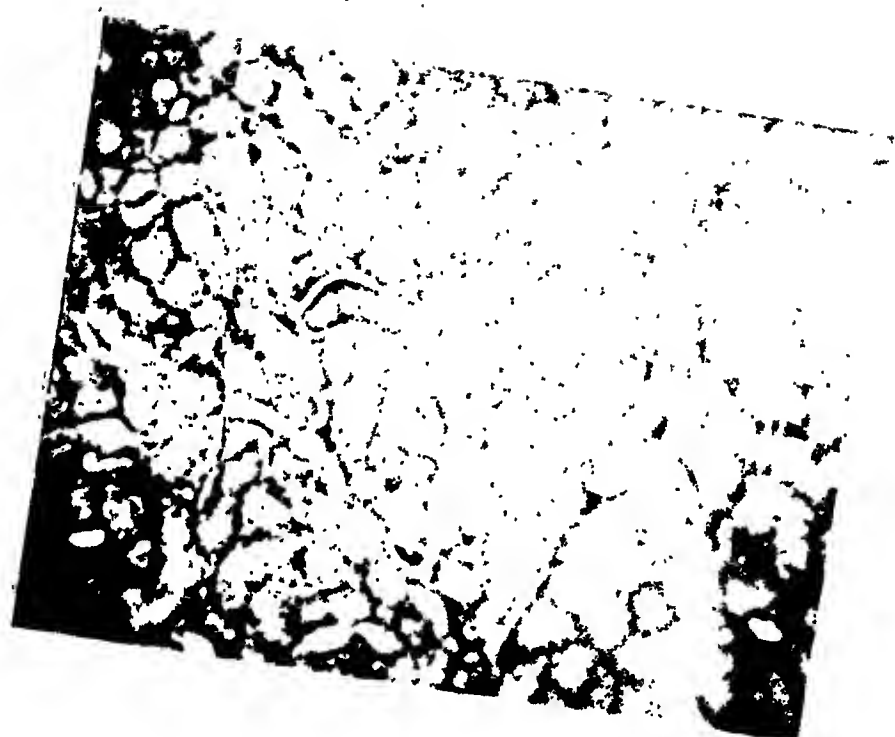
Fig. 14 (experiment 45).—Right testis of adult dog in which the internal spermatic artery and all the veins were ligated, leaving only the vessels accompanying the vas deferens intact; testis removed 108 days later; the parenchyma of the gland and interstitium as well were destroyed; only fibrous connective tissue remained.

Feb. 29, 1924, sixty-four days later, castration was done. Both testes were reduced in size. The microscopic section showed a fairly normal testis with all the mature germinal cells present. Only a few tubules at the periphery exhibited degenerative phenomena.

EXPERIMENT 48.—March 3, 1925; a large adult dog.

The left testis and spermatic cord were not touched. On the right the internal spermatic artery and anterior vein in the pampiniform plexus were cut and ligated, leaving the posterior vein and the vas deferens and the vessels accompanying it intact.

June 9, ninety-eight days later, castration was done. The left testis was about twice as large as the right. Microscopically the left was normal. On the right





were no spermatozoa. In many tubules at the periphery most of the cells had disappeared. (Separation of the vessels in the pampiniform plexus is always difficult because of the small size of the vessels. In all these experiments the internal spermatic artery, when cut, was allowed to spurt to be certain that the artery had really been severed. In the veins the procedure is not quite so simple. From what has happened in ligation of the internal spermatic artery alone and then ligation of the artery with one vein, and ligation of all the vessels save those accompanying the vas deferens, it is observed that only the latter procedure produces a complete degeneration. Separation of the vessels is attended with even greater difficulty just above the testis.) The left was fairly normal. There was elaboration of all the mature germinal cells. A few atrophic tubules were noted at the periphery.



Fig. 16.—Testis of a man of 22; three years previously this testis was high in the inguinal region; in order to place it in the scrotum, all the vessels except those accompanying the vas deferens were severed; the bare outline of a few tubules still persists.

EXPERIMENT 52.—Sept. 16, 1925; a large adult dog.

The internal spermatic artery and the anterior vein in the pampiniform were severed and ligated leaving the posterior vein intact on the right. On the left both veins in the pampiniform plexus were severed and ligated, leaving the internal spermatic artery intact. On both sides the vessels accompanying the vas deferens were not disturbed. The vessels in each instance were exposed in the upper portion of the inguinal canal.

December 15, ninety days later, both testes were removed. The right testis was considerably reduced in size. The left testis was about normal size.

Microscopically, on the right there were areas of fibrosis, especially at the periphery. Elaboration of most of the adult germinal cells in the remaining tubules was noted. The normal condition was present in most tubules of the left.

germinal epithelium was present in both. No degenerative phenomena were present.

EXPERIMENT 18.—July 28, 1925; pup 4, aged 5 months.

The right testis was placed in the peritoneal cavity; the left was allowed to remain in the scrotum.

August 18, twenty-one days later, castration was done. Both testes were the same size. Microscopically, the germinal epithelium was from two to three layers in thickness. Both were histologically alike. No degenerative phenomena were present and no adult germinal cells.

EXPERIMENT 19.—July 31, 1925; a small pup, aged from 2.5 to 3 months.

The right testis was transplanted into the inguinal area; the left was not touched.

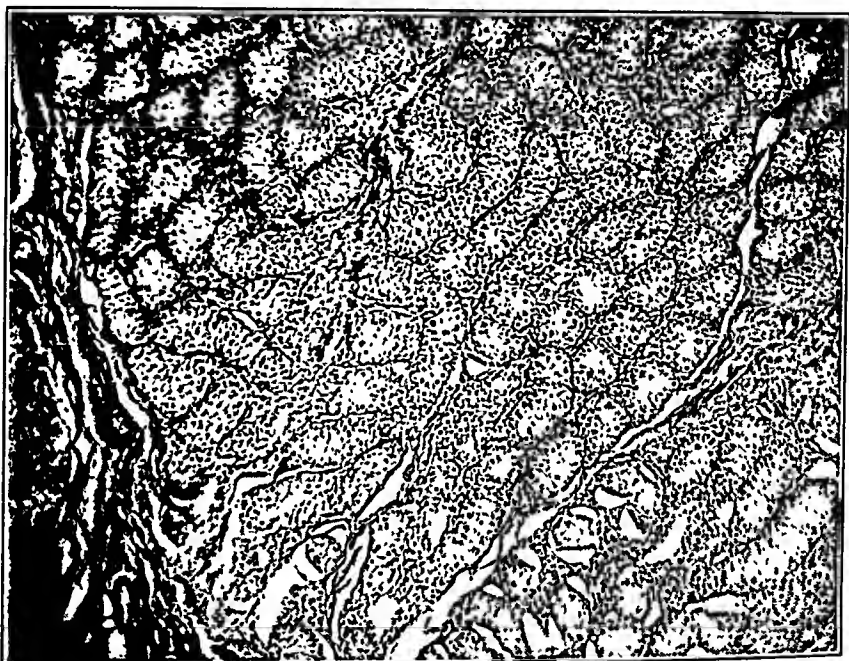


Fig. 5.—Right testis of same dog as shown in figure 4 after having been in the peritoneal cavity for twenty days; the only germinal cells present in either section are the spermatogonia; there is no appreciable histologic difference ( $\times 100$ ).

August 27, twenty-seven days later, castration was done. Both testes were the same size. Microscopically, a many layered germinal epithelium was present. No degenerative phenomena were observed. Histologically they were similar.

EXPERIMENT 20.—July 31, 1925; a small pup, aged 6 weeks.

The right testis was transplanted into the inguinal region; the left was not touched.

August 27, twenty-seven days later, castration was done. Both testes were of the same size. Microscopically, the central lumen was not established. There was a single layered germinal epithelium. The interstitium was prominent. Both were alike, and no degenerative changes were present.

The transplanted testis when removed, after a few days in its new environment, though appearing grossly much the same as its fellow in the dog's scrotum, microscopically shows a marked degeneration of the

of diverticula and a thinning of the germinal epithelium. As all these testes were from men of advanced years, this finding is compatible with what has been described as the normal condition in old men.<sup>253</sup> In two men of 81, spermatozoa were observed. It is said that spermatogenesis disappears in the senile testis.<sup>111</sup>

#### EXAMINATION OF TESTES OF MEN DYING OF ACUTE AND CHRONIC FEBRILE DISEASES

##### SERIES VIII

Thirty-five testes were examined in this series. A scattered disappearance of the germinal epithelium appears in a number of testes of

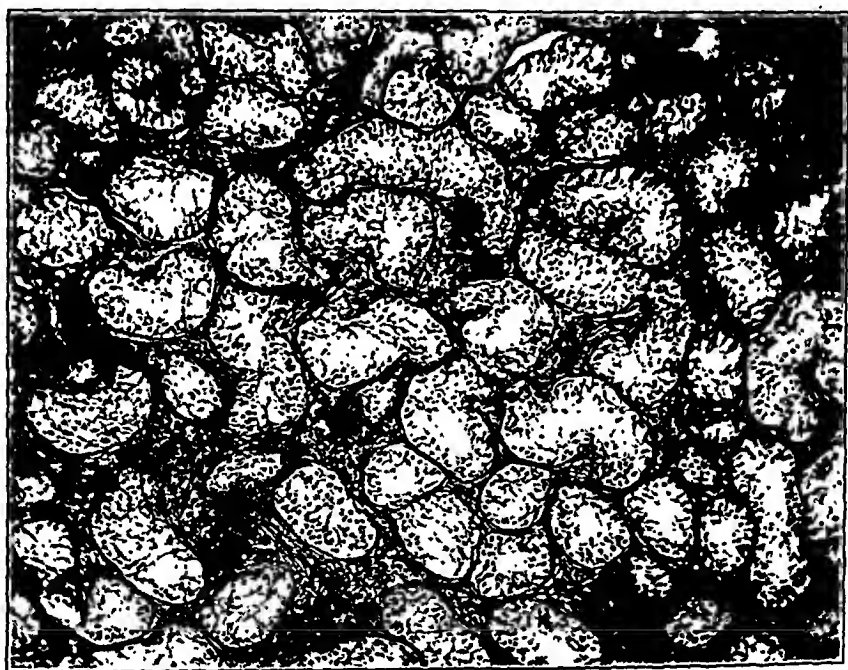


Fig. 17.—Inguinal testis of a boy of 17, removed during the course of a hernia operation; spermatogonia are in evidence; the more mature germinal cells, however, are absent; comparison should be made with a transplant testis.

persons dying of acute and chronic diseases. In a few the testis preserves the normal condition. The more uniform finding, however, appears to be a mild degenerative process in which the mature germinal cells disappear. Disappearance of the spermatogonia rarely occurs so that the normal condition may be quickly reestablished after the removal of the toxic agent.

##### COMMENT

The histologic change that occurs in the adult testis with removal from the scrotum has long been known. In 1891 Piana\* interfered

\* Piana: *La Clinica Veterinaria*, 1891, quoted by Stilling.<sup>260</sup>







Walker<sup>285</sup> and Fukui<sup>104</sup> have recently stated that the internal secretion arises in the spermatogenous elements. Though the internal secretion has not been definitely shown to take origin in the cells of Leydig, the weight of evidence would point toward these as its source.<sup>118, 119</sup> In cryptorchids in whom the secondary sex characters are preserved there is no germinal epithelium. Many of the Sertoli cells are in a degenerate state. Though the Sertoli cell cannot be ruled out of consideration as can the germinal cells, the available evidence would indicate that the interstitial cell is responsible for the internal secretion of the testis.

The difficulty of preserving as a graft so highly specialized a tissue as a testis is apparent. When all the vessels to the testis are ligated, a mere nubbin of scar tissue results. In such an experiment, an autograft is really created. Certainly the circumstances for a good result should be more favorable here than in a homo or hetero transplant. Lichtenstern<sup>165</sup> states that undoubtedly good results are obtained by homotransplantation of testicular grafts. Retterer's and Voronoff's<sup>222</sup> histologic studies of their own experiments on animals, however, would indicate the contrary.

In 1889 Brown-Sequard<sup>36</sup> demonstrated the efficacy of subcutaneous injections of testicular extract. Recently these results have been confirmed.<sup>255</sup> The administration of the active principle of the internal secretion of the testis by the hypodermic needle would appear to be more rational than the two procedures practiced today.

Neither is there any agreement as to the effect on the testis following the ligation of its blood vessels. Miflet<sup>181</sup> in 1879 held as a result of ligation of the internal spermatic artery in the dog that this vessel is an end artery and that its ligation causes atrophy of the testis. Examination of his protocols shows, however, that the degeneration in the germinal epithelium is only at the periphery of the tubules. Since then numerous anatomic researches on the blood supply\* of the testis have been made in both man and dog. Janisch,<sup>135</sup> Colle,<sup>48</sup> Worms<sup>207</sup> and Picque and Worms<sup>210</sup> all state that the testis derives its arterial blood supply from three sources. The main source is through the internal spermatic artery which establishes anastomoses with the artery to the vas deferens and the external spermatic artery from the deep epigastric. No anastomotic flow occurs between the scrotal vessels and the arteries in the spermatic cord. After section of all the vessels to the testis, however, Colle<sup>48</sup> states that an anastomosis may obtain between the peripheral ends of the funiculoepididymospermatic system and the scrotal vessels sufficient to prevent gangrene of the testis when the usual source is interrupted. Pellanda and Neuhaus<sup>190</sup> fail to mention the external

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\* Enderlin<sup>80</sup> states that the testis will tolerate total occlusion of the blood supply for sixteen hours.

The testes of several mature dogs were transferred to the peritoneal cavity and inguinal region. After the lapse of a period of time, one testis was removed to determine the amount of injury and the other was replaced in the scrotum. These were subsequently removed and comparisons with the control organ made to determine whether regeneration of the germinal epithelium in the seminiferous tubules had occurred. In every instance but two marked regeneration of the germinal epithelium with formation of spermatozoa had occurred. The photomicrographs of the controls and the testis replaced in the scrotum illustrate well the ability of the germinal epithelium to be regenerated if the testis is redeposited in the scrotum. When the testis remains too long in the peritoneal cavity and most of the spermatogonia are destroyed the regenerative ability of the germinal epithelium is lost. This occurred in the fourth dog in this series. After remaining for 101 days in the peritoneal cavity, this testis was replaced in the scrotum. No evidence of regeneration was apparent after forty-two days. In the fifth dog in this series the testis had retracted out of the scrotal pouch and was found at the lower end of the inguinal canal. The physiologic position of the testis at the bottom of the scrotum must therefore be restored. In all these scrotal repositions, the testis was sutured to the bottom of the scrotum. The purse-string suture used at the upper end of the scrotum prevents retraction out of the scrotal pouch, but this is not the proper location of the testis. This point will be discussed at greater length when the surgery of undescended testes is considered.

#### LIGATION OF THE VAS DEFERENS

##### CASE IV

Ligation of the vas deferens was carried out on one side, and on the other all the vessels to the testis including the vessels accompanying the vas deferens were severed. Only the vas itself remained intact on this side.

EXPERIMENT 38.—Aug. 23, 1923; a pup, aged about 5 months.

The right vas deferens alone was ligated and severed on the left. All the vessels were cut and tied; only the vas itself was left intact.

September 7, fifteen days later, castration was done. There was only a small piece of scar tissue on the left. The right testis was of the same size as at the original procedure. Microscopically, the right showed a prepuberty testis in which no germinal cells beyond the spermatogonia had been formed. There were no degenerative changes. In the left only fibrous connective tissue remained.

EXPERIMENT 20.—Aug. 24, 1923; a large young dog.

The right vas deferens only was ligated and severed. On the left all the vessels to the testis and epididymis were severed and doubly ligated.

December 27, 125 days later, castration was done. Measurements of the right testis showed that it had increased in size since the previous procedure (to 4 by 3 by 2.5 cm. from the previous 3 by 2.3 by 2 cm.). Microscopically, in the right all the mature germinal cells were present, including spermatozoa. No sections were made of the left.



those cases where it is necessary to divide them in order to bring the testicle well down into the scrotum." Since then, this procedure has frequently been practiced with varying results.<sup>136, 152, 184, 206, 290</sup>

Previously Griffiths had demonstrated on dogs that ligation of all the vessels except those accompanying the vas deferens always results in atrophy. Griffiths<sup>113</sup> performed this experiment five times and only in one instance was the testis normal. But in that case the "ligature could not be found and free communication had become established as injections passed readily along the spermatic artery into the testis." In all the other instances cyanotic destruction, sloughing testis or extensive degeneration were noted. Griffith<sup>118</sup> did one experiment ligating the internal spermatic artery and the deferential artery; necrosis of the testis followed. In ligations of the internal spermatic artery alone, destructive changes were noted in the testes examined a few days after the ligation. But when a longer period of time intervened, the testis was found to be normal. Griffiths reasoned that the establishment of the normal histology was due to collateral circulation.

Alessandri<sup>4</sup> found that ligation of the spermatic artery and veins in the pampiniform plexus always caused degenerative changes. Ligation of the artery alone occasioned nutritive disturbances but no atrophy. Ligation of the artery to the vas deferens was without effect. Martini observed only a transitory effect on the testis after ligation of the internal spermatic artery.

Gangrene of the testis did not occur in experiments done by Moschowitz<sup>196</sup> in which the main bundle of vessels was ligated in dogs. Gessner<sup>105</sup> observed atrophy of the germinal epithelium of the testes in five dogs in which the same procedure was carried out. More recently Koyano<sup>147</sup> has practiced ligation in dogs of the vessels extraperitoneally internal to the anterior superior spine in order to eliminate the factor of trauma. In his hands, ligation of the internal spermatic vein provoke the least change in the germinal epithelium. Ligation of the internal spermatic artery and vein was followed by slight but more definite degenerative phenomena in the germinal epithelium. The greatest amount of atrophy Koyano<sup>147</sup> observed after ligation of the internal spermatic artery alone. He therefore believes that the procedure of vessel section in the treatment of undescended testis is rational and justifiable.

Haberer<sup>117</sup> has worked out in detail the venous outflow of the testis and epididymis. A great venous communication exists about the testis and epididymis Haberer states, and he finds that the blood may leave by four possible routes. Most of the return occurs through the internal spermatic vein, a lesser amount through the external spermatic vein, and portions through the vein of the epididymis and the vein of the vas deferens. The external spermatic vein empties into the deep epigastric;

there was a large area of fibrosis in the midportion of the testis. Most of the tubules showed normal spermatogenesis with spermatozoa present.

EXPERIMENT 49.—March 17, 1925; a large mature dog.

The internal spermatic artery was ligated and severed on both sides.

June 9, eighty-four days later, castration was done. Both testes were smaller than at the original procedure. Microscopically there was fibrosis in these areas. Spermatocytes and spermatids were present but no spermatozoa (a well elaborated germinal epithelium, however, which could develop normal spermatogenesis).

EXPERIMENT 50.—March 25, 1925; a large adult dog.

On the right the internal spermatic artery was ligated and severed. On the left the internal spermatic artery and anterior vein in the pampiniform plexus were ligated, leaving the posterior vein intact, as well as the vas deferens and its accompanying vessels.



Fig. 15.—The testis of a boy of 19 who, six years previously, had an orchidopexy performed in which all the vessels, except those accompanying the vas, were divided, in order to place the testis in the scrotum; the similarity to figure 14 is apparent.

July 20, 117 days later, castration was done. Both testes were smaller. Microscopically, both appeared much alike. Spermatogenesis was present in most tubules. A few were empty. Numerous spermatozoa were present.

EXPERIMENT 51.—April 9, 1925; a mature dog.

On the right the veins in the pampiniform plexus only were ligated and severed. The internal spermatic artery and the vas deferens and its vessels were left intact. On the left the internal spermatic artery and the anterior vein in the pampiniform plexus were ligated, leaving the posterior vein and the vas deferens and its vessels intact.

July 20, 102 days later, castration was done. Both testes were smaller. On the right a fairly well differentiated germinal epithelium was present. There

testis to division of the internal spermatic artery and vein in the retroperitoneal space do not therefore obtain in the operation as done for undescended testes.

Ligation of the internal spermatic artery and pampiniform plexus always results in atrophy of the germinal epithelium and interstitium of the testis as well. Statements <sup>122</sup> to the effect that ligation of these vessels is without deleterious effect on the testis will not bear investigation. A comparison of the photomicrograph that represents the testis recovered from a patient on whom orchidopexy with vessel section had been done a few years previously with what obtains in the dog is quite convincing as to what happens to the testis when all the vessels except those accompanying the vas deferens are divided.

Transference of the testis from the scrotum in adult dogs always results in atrophy. Whether the testis is placed in the retroperitoneal region, the peritoneal cavity or the inguinal region, degeneration of the germinal epithelium always occurs. Ligation of the vas does not cause atrophy. Ligation of the internal spermatic artery and with it the nerve supply to the testis does not cause a disseminated destruction of the seminiferous tubules.

When the testes are replaced in the scrotum, a fairly normal condition is reestablished. Spermatozoa are found in the tubules and in the epididymis. Moore <sup>191</sup> has recently also shown that regeneration of the germinal epithelium occurs in the seminiferous tubules of guinea-pigs and rabbits after scrotal replacement following elevation to the peritoneal cavity.

The scrotum, therefore, is essential to the normal development of a testis, and Moore <sup>192</sup> has rightly ascribed to the scrotum an important physiologic function.

Just what the scrotum affords the testis that is lacking elsewhere has been an interesting but mystifying problem. Piana concluded from his experiments that the temperature in the abdomen was unfavorable.<sup>200</sup> More recently Turner <sup>275</sup> examined the testes of perch during different seasons and found that with fall in temperature of the water spermatogenesis began and ceased with increase in temperature. Later Crew <sup>61</sup> pointed out that the scrotum was well equipped for local heat regulation in that no insulating layer of fat intervened between the skin and the dartos muscle; he suggested that this circumstances accounted for the aspermatic condition of cryptorchid testes. Benedict and Slack <sup>11</sup> had previously demonstrated that a constant body temperature is only reached at a depth of from 6 to 8 cm. and that a temperature gradient of 5 degrees obtains between the body cavities and the external surface. Fukui <sup>102, 104</sup> in Japan has recently observed that exposure of the dog's scrotum to the sun at temperatures of 44-49 C. for two hours produced degenerative changes in the germinal epithelium. The same occurred if the dog's

Invariably after ligation of all the vessels in the spermatic cord except the artery to the vas deferens, complete atrophy of the germinal epithelium and interstitium occur such that the parenchyma of the gland is replaced by fibrous tissue. The epididymis continues normal. In the animals in which castration was done after a shorter interval, necrosis of the parenchyma of the testis was observed. After ligation of the internal spermatic artery, a diminution in size of the testis is constantly noted. Many of these testes, however, appear fairly normal throughout the greater portion of the gland on microscopic examination. Here and there at the periphery atrophic tubules occur. A lesser number showed this partial degenerative process fairly well disseminated throughout the greater portion of the gland. Ligation of the internal spermatic artery with either the anterior or posterior group of veins in the pampiniform plexus leads to a rather more marked degenerative process than does ligation of the artery alone. When interruption of all the blood supply to the testis occurs, that is, ligation of the internal spermatic artery and veins in the pampiniform plexus together with the vessels accompanying the vas deferens, the testis shrinks up to a mere nubbin of scar tissue. Gangrene was observed only once and in this instance infection was present.

#### EXAMINATION OF UNDESCENDED TESTES IN MAN

##### SERIES VI

Seventeen testes that had failed to reach the scrotum were obtained for examination. Unfortunately no prepuberty undescended testes were available. In the testes of old subjects, even the seminiferous tubules had a hyaline appearance. The interstitial cells appeared increased in number. In two testes spermatogonia were observed. In the testis of a boy of 17 spermatocytes also were present. The similarity between the undescended testis in man and the experimentally ectopic testis of the dog is apparent.

#### THE TESTIS IN LARGE SCROTAL HERNIAS AND HYDROCELES

##### SERIES VII

Nine testes that were removed in the cure of large old scrotal hernias were examined. Fourteen testes were obtained for examination from patients who had had large hydroceles over a long period of time (8-12 ounces [236 to 355 cc.] of fluid present) and six were examined in whom both a scrotal hernia and a hydrocele had existed together.

As long as the testis continues in the scrotum, the elaboration of the adult germinal cells is possible. In the testes of men in whom large scrotal hernias or hydroceles had been present for years, the normal condition prevailed. The only anatomic peculiarity observed was an apparent increase in size of the lumen with a tendency to the formation

disturbances,<sup>195</sup> chronic debilitating diseases,<sup>121, 146, 277</sup> chronic alcoholism,<sup>288</sup> starvation<sup>55, 170, 248</sup> and vitamin free diets<sup>5, 290</sup> have all been known to bring about the same condition. Adler<sup>2</sup> reports injury to the seminiferous tubules after iodine administration. In one case coming under my observation this change was not noted.

In 1903 Albers-Schönberg<sup>3</sup> called attention to the sterility that occurs after exposure to the roentgen rays. Numerous observations<sup>34, 35, 125, 148, 246</sup> since then have corroborated this finding. As in the cases of starvation, acute and chronic febrile diseases, the removal of the cause enables the seminiferous tubules to be rehabilitated. So here the effect is usually transitory, unless the spermatogonia have been destroyed. In the prepuberty testis in which spermatogenesis has not been established

TABLE 1.—Average Weight of Testis from Birth to Eighteen Years (Mita)

	Gm.		Gm.		Gm.
New-born .....	0.5	1 year .....	0.7	2 years.....	1
5 years.....	1.16-1.23	11 years.....	1.93	12 years.....	1.9
13 years.....	4.50	15 years.....	11	17 years.....	16
18 years.....	17				

TABLE 2.—Average Weight of Testis from Birth to Fifteen Years (Wwedensky)

	Testis Weight in Grams		Epididymis Weight in Grams	
	Right	Left	Right	Left
New-born .....	0.2	0.196	0.12	0.12
3 months.....	0.32	0.51	0.19	0.19
1 year.....	0.72	0.71	0.2	0.2
1-5 years.....	0.86	0.87	0.19	0.2
8-10 years.....	0.8	0.82	0.24	0.24
11 years.....	1.2	1.3	0.4	0.39
12 years.....	1.5	1.5	0.42	0.42
14 years.....	1.48	1.5	0.52	0.52
15 years.....	6.79	6.83	1.00	1.00

this reaction is minimal.<sup>294</sup> No degenerative phenomena are in evidence, but edema and red blood cells may be present.\*

Wwedensky<sup>298</sup> in an examination of forty-six cases from birth to fifteen years found the results given in table 2.

Elsewhere only brief mention has been made of the anatomy of the prepuberty testis. The general conformation of the testis as in the adult is ovoid, but bean shaped organs with a concave posterior aspect and a prominent hilum are not infrequent. Büdinger<sup>39</sup> has stressed this finding as significant in incompletely descended testes, but Gundobin<sup>110</sup> says this is not unusual in the normal. Mita<sup>183</sup> has weighed and microscopically examined 113 testes in ages from birth to 18 years. All but twenty-two of these were in children under 13. He appends a table of average weights (table 1), the amount being designated in grams or fraction thereof for one testis.

\* Schultze<sup>241</sup> and Simmonds<sup>244</sup> state that this is a frequent finding in the apparently normal new-born.

with the descent of the testis in white rats and observed a marked atrophy of the germinal epithelium. Griffiths<sup>112</sup> in 1892 was the first to observe this change in dogs. He also noted the difference in reaction to abdominal transference of the testis in young and old dogs. In 1894 Stilling<sup>200</sup> placed the testes of twenty rabbits in the peritoneal cavity by severing the gubernaculum without even closing the internal ring; atrophy occurred in every instance. In 1905 Matsuoka<sup>178</sup> transplanted the testes of seven rabbits into the abdominal wall. At a subsequent date he cut the vessels and the vas deferens; a necrosis of the testis resulted. Schmidt<sup>235</sup> in 1913 confirmed Griffiths'<sup>112</sup> previous observa-

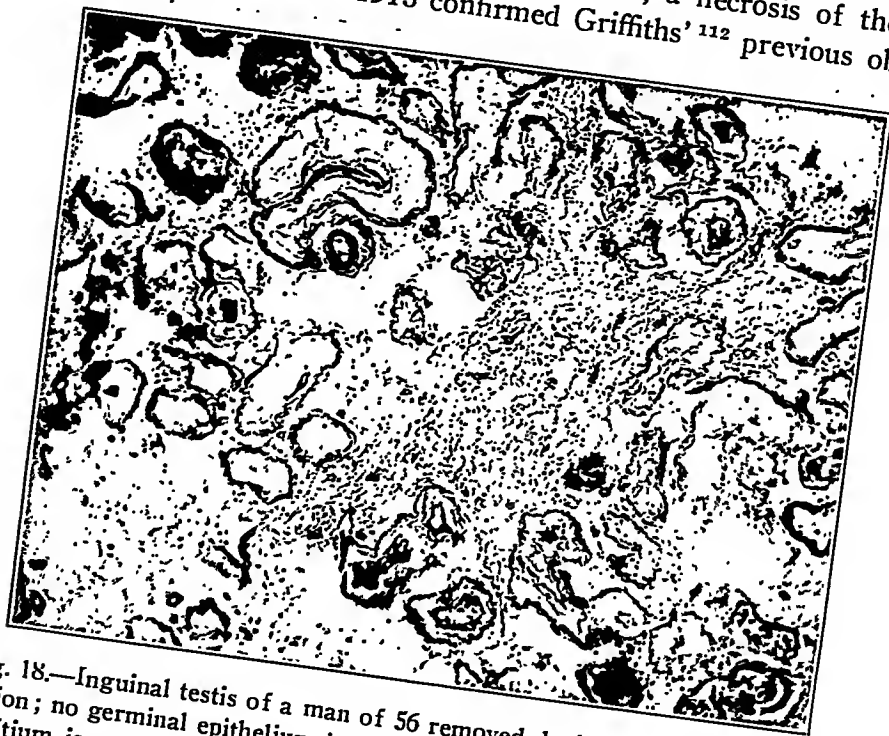


Fig. 18.—Inguinal testis of a man of 56 removed during the course of a hernia operation; no germinal epithelium is present; only a few Sertoli cells remain; the interstitium is normal.

tions. More recently Moore,<sup>189, 190, 191</sup> Fukui<sup>102, 103, 104</sup> and Fukuiyiro<sup>101</sup> have noted the same effect.

Piana concluded from his experiments that the temperature in the abdomen was unfavorable for the testis.<sup>200</sup> Griffiths<sup>112</sup> could give no accurate answer as to the cause of the atrophy, but thought that the removal of the cremaster was responsible. Stilling<sup>200</sup> postulated that the kinks in the epididymis were causative. Schmidt<sup>235</sup> believed that the lack of fixation of the testis transplanted into the abdomen and the abdominal pressure were responsible for its atrophy. Both Moore<sup>190, 191, 193</sup> and Fukui<sup>103, 104</sup> believe that the thermal factor is responsible for the degenerate condition of the testis removed from the scrotum.

and the occurrence of spermatogenesis does a marked change in the histology occur. In the testis of the new-born there is no real lumen in the tubules. Two or three irregular rows of cells almost completely fill the tubule. The spermatogonia may be present singly or in groups. Spangaro<sup>253</sup> states that the proportion of spermatogonia to Sertoli cells is from 1:35 to 1:200 to 1:400. In the preadolescent period the only changes that occur are the establishment of a central lumen; a definite arrangement of the Sertoli cells, and an increase in the number of spermatogonia, such that the proportion of spermatogonia to Sertoli cells increases to 1 spermatogone to every 12-20 Sertoli cells. However, Spangaro<sup>253</sup> states that a definite relationship between the number of

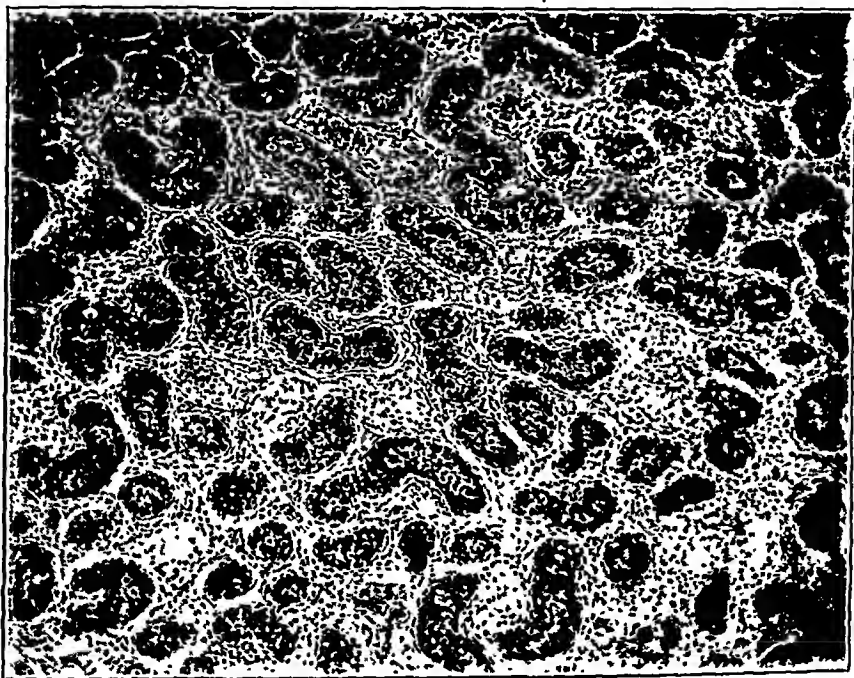


Fig. 23.—Testis of a 5 year old child; there is more definite outline of tubules than in figure 22 and beginning lumen formation.

spermatogonia in the tubules and the age of the child does not exist. The morphology of the spermatogonia themselves throughout the period from the first to the fourteenth year Spangaro finds is much the same as that of the new-born.

Mita<sup>183</sup> concurs in all of Spangaro's findings, but states that a rapid rate of growth occurs between the twelfth and the thirteenth years. Spermatogenesis was first observed at 13.

Wwedenski<sup>208</sup> classifies the changes that occur in the testis of the young in the following manner.

During the first fetal period from the fourth to the eighth month the tunica albuginea consists of but one layer and is of fine connective

of the vas deferens. Oslund<sup>202</sup> calls attention to the fact that the testis must be known to be in the scrotum. In many cases, the ligation has been practiced on rodents in which the testes may be retracted out of the scrotum at will. Oslund<sup>202, 203</sup> and Moore and Quick<sup>192</sup> have not observed hypertrophy of the interstitial cells following vas ligations. In the experiments done by me the germinal epithelium did not disappear, nor was hypertrophy of the interstitium noted. When the testis is known to be in the scrotum and a sufficient length of time intervenes to preclude damage as a result of operative trauma, ligation of the vas deferens should be without event in normal healthy animals. Certainly



Fig. 19.—Scrotal testis of a man of 81 who had a large scrotal hernia and hydrocele for many years; the normal condition is present; the lumina appear unusually large and diverticula in the tubules are present—both normal findings in the testis of the aged.

any kinks that may occur in the vas deferens or epididymis when the testis is not in the scrotum is not the cause of the atrophy.

The rejuvenation of senile animals noted by Steinach<sup>258</sup> following this procedure is difficult to account for. In the results obtained by Steinach<sup>258</sup> and Sand<sup>230</sup> in patients the psychic effect or reaction to the operation may in a large measure discount the credit due the procedure. Certainly no histologic effect follows interruption of the vas in man or animals. In congenital absence of the vas deferens and after a number of years occlusion following gonorrheal epididymitis, the histology of the seminiferous tubules and interstitium still remain normal.<sup>140</sup>



It is true that the spermatogonia in the mature dog's testis after a prolonged transference from the scrotum do disappear, and when replaced in the scrotum the mature germinal cells cannot be regenerated. When spermatogenesis supervenes the resistance shown by the resting spermatogone of the young animal is greatly diminished and it becomes as the other germinal cells, though in less degree, the victim of its new environment.

The ability of the testis to regenerate its structure has been the subject of a number of researches.<sup>110, 133, 231</sup> Anatomists are divided concerning the mode of origin of the germinal cells. One school believes that the Sertoli cells are the progenitors of the entire germinal epithelium,<sup>214</sup> the other that the Sertoli cells have only a nourishing function<sup>10</sup> and that the mature sexual cells are all developed from the spermatogonia that are present at birth. If the dog's testis is allowed to remain in the peritoneal cavity until all the spermatogonia have disappeared, no regeneration of the germinal epithelium is observed when the testis is replaced in the scrotum.

Before puberty the experimentally undescended testis develops much like its fellow in the scrotum. But if allowed to continue in its new habitat, it will make an attempt to maintain a normal spermatogenesis, but degenerative changes frustrate its attempts.

In how far can these data be construed to have any bearing on the human testis? It has been shown that no destructive changes are observed in the testes of young dogs when transferred to new surroundings outside the scrotum. It has been offered in explanation that the germinal cells in the testis at this time are few, the testis itself is small and only the onset of spermatogenesis makes the testis sensitive to injury. Transference of the testis in the adult dog from the scrotum always results in atrophy, but replacement in the scrotum at not too late a date restores the spermatogenic function again.

Frequent reference has been made throughout this article to Moore's excellent work on experimental cryptorchidism. Recently<sup>191</sup> he has shown that the testis of the rat and guinea-pig when placed in the peritoneal cavity will regenerate its germinal epithelium if redeposited in the scrotum. He concludes that this unquestionably demonstrates that the undescended testis is degenerate because of its position. The first experiments in this study were on guinea-pigs and rabbits. It occurred to me early, however, that in order to draw any conclusions relevant to the undescended testis in man an animal must be used in which the testis is always resident in the scrotum. The testes of guinea-pigs and rabbits, like those of all rodents, can be drawn up at will into the abdomen.<sup>203</sup> Tandler and Grosz<sup>204</sup> studied the seasonal changes in the testes of the mole. They found that during rest in the month of March the germinal epithelium reaches its highest development and then gradually wanes.

spermatic artery in their studies of the arterial circulation of the testis. Pellanda\* also minimizes the importance of the deferential artery. Ludwig and Tomsa<sup>172</sup> state that the blood supply of the testis in the dog is the same as in man. Griffiths<sup>113</sup> finds that the vascular arrangement in man and dog are much the same. Schmidt<sup>235</sup> has studied the circulation of the testis in both man and dog and states that the comparison is not so complete as Ludwig and Tomsa<sup>172</sup> indicate. The source of supply is the same but the disposition of the vessels slightly different. The internal spermatic artery is more twisted in the dog and doesn't divide into two branches as soon as in the human being. Ellenberger and Baum<sup>79</sup> state that an anastomosis obtains in the dog between the three

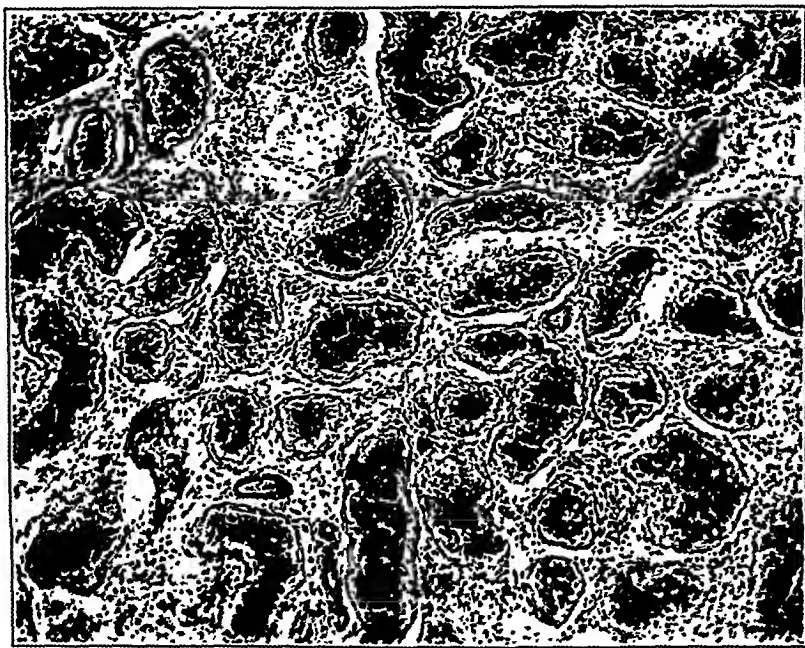


Fig. 20.—Testis of a man of 24 ill four years with pulmonary tuberculosis; no mature germinal cells are present; spermatogonia, however, are numerous.

vessels mentioned above. Experiments on the dog's testis are therefore applicable in the case of man.

In 1902 Mignon<sup>182</sup> in France advocated the section of all the vessels in the spermatic cord, with the exception of those accompanying the vas deferens, as a measure to aid low fixation of the testis in the scrotum in orchidopexy for incomplete descent. The following year, Bevan<sup>17</sup> independently in this country concluded from operations on varicocele in which he had sacrificed all the vessels in the spermatic cord except those accompanying the vas and in which no apparent interference with nutrition had occurred, that these vessels "could be safely sacrificed in

\* Pellanda: *Internat. Monatschr. f. Anat. u. Phys.* 20:240-265, 1903.

prepuberty or puberty testes. In their following article they report twenty-six cases; eleven of which were in the young. Excerpts from the descriptions of the testes in their second publication on the subject are tabulated. Their conclusions and findings were the same in both articles.

Of the fourteen undescended testes examined in the first series, eight were said to be normal for the age. (Included among these, eight were testes of subjects from 11 to 14 years.) One in a boy of four was tuberculous. Of the remaining five, all occurred in subjects 13 years of age and the description given these was that the germinal epithelium was not commensurate with what one should expect at this age. From the researches of Spangaro,<sup>253</sup> Wwedenski<sup>298</sup> and Mita,<sup>183</sup> however, it is apparent that the histology of the new-born child's testis and that of the boy of 13 before spermatogenesis occurs are very similar.

Tabulation of descriptions of the young testes in Felizet and Branca's second series follows:

1. Observation 29. Age, 6. Spermatogonia in repose; some of these in mitosis.
2. Observation 33. Age, 9. The seminal tubules were constituted by epithelial cells and a number of male ovules (spermatogonia). "The canals are full but rare." The diameter of the canals varied from 26 to 45 microns. Only a maximum of thirteen seminal canals could be counted in any one fixed field with a number 4 objective. (In a footnote at the bottom of the same page they state that as many as from twenty-five to thirty tubules have been counted in another undescended testis in a boy of 9.)
3. Observation 34. Age, 15. Numerous spermatogonia in mitoses; degenerative changes also apparent.
4. Observation 36. Age, 14.5. Numerous spermatogonia, some in repose, others in mitosis; also spermatocytes.
5. Observation 39. Age, 17. Spermatogonia and spermatocytes; also degenerative changes.
6. Observation 40. Age, 8. Tuberculous testis.
7. Observation 42. Age, 6. Spermatogonia present, as many as five per tubule; lumen present in most of the tubules; in places desquamated elements from "male ovules" and Sertoli cells. (The latter statement is certainly open to doubt.)
8. Observation 44. Age, 12.5. Numerous spermatogonia in repose; many in process of division; also spermatocytes of first order; a number of Sertoli cells were in the process of degenerating and contained fat.
9. Observation 45. Age, 12. Some of cells were filled with fat; some were desquamating into the central lumen; did not stain as well as normally.
10. Observation 46. Age, 14. Chromatolysis of some spermatogonia; others in the process of proliferation; a few spermatocytes were present in several stages of mitosis.
11. Observation 47. Age, 14. A few areas of degeneration; some infantile tubules present; some showed vacuolated spaces from which the germinal cells were disappearing; some tubules were of normal diameter and showed spermatogonia and spermatocytes in mitosis.
12. Observation 50. Age, 14. Spermatogonia and numerous spermatocytes; also evidences of degeneration.

the veins of the vas deferens into the plexus about the seminal vesicles, and the vein of the epididymis into the internal spermatic. Anastomoses between the veins, it is apparent, therefore, occur only in the lower portion. Interruption of the veins in the pampiniform plexus below the anastomoses will interfere considerably more with the circulation in the testis than the ligation of the internal spermatic vein alone high in the extraperitoneal region. This fact has long been known in the treatment of varicocele,<sup>12, 131, 132, 146, 213</sup> and the high ligation of the vessels has superseded the scrotal resection of veins. Koyano's observation, therefore, that ligation of the internal spermatic artery and vein in the

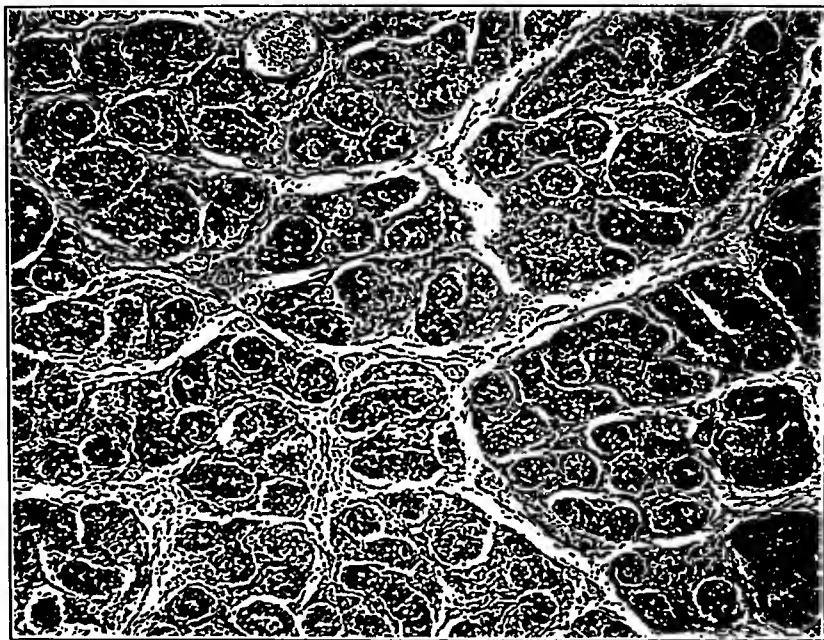


Fig. 21.—Testis of a seven months premature infant (one of triplets; the histologic picture was the same in all testes; the testes in each instance were still within the abdomen); the lumen has not been established in the tubules; Sertoli cells and spermatogonia alone constitute the walls of the seminiferous tubules; red blood cells are present in the intertubular spaces.

extraperitoneal region is without considerable effect on the histology of the testis is interesting, but amounts to virtually the same thing as my ligation of the internal spermatic artery and anterior group of veins in the pampiniform plexus; this ligation, as I have shown, may be compatible with a fairly normal spermatogenesis in the tubules. Marked diminution in size of the testis, however, occurs.

In the operation as practiced for scrotal fixation of the undescended testis, when vessel section is done, all the vessels except those in immediate relation with the vas are severed. Only rarely are the vas and the vessels that accompany it of insufficient length. The reaction of the

all these instances, however, the operation was done after puberty \* and no record was obtained as to the absence or presence of spermatozoa before the operation. Because of the age at which the operation was done, I feel that these must be regarded as instances of those cases in which a temporary spermatogenesis may occur in cryptorchids.

All these facts do, however, demonstrate that the undescended testis goes through the state in which a mature germinal epithelium is elaborated. The very fact that a certain number of cryptorchids' testes are functional in an abnormal habitat demonstrates that they are not *ab ovo* imperfect. The fact that degenerative changes appear, as Felizet and Branca<sup>86, 89</sup> have described, in the undescended testis at puberty is significant that the more mature germinal cells are produced, for the immature or prepuberty testis does not exhibit degenerative changes. Similarly, the testis of the young dog undergoes no change when elevated into the inguinal region or peritoneal cavity. The adult dog's testis is subject to degenerative changes if removed from the scrotum, but when replaced in its normal environment before all the spermatogonia have disappeared, the histology of the tubules can be restored.

Given the stimulus to development, therefore, that the scrotum affords, the undescended testis of man, if successfully placed in the scrotum before the changes incident to puberty occur, should develop normally.

#### THE SURGERY OF THE UNDESCENDED TESTIS

No attempt will be made here to discuss the numerous procedures that have been suggested to deal with the undescended testis. The principles involved in the treatment of the condition will be briefly considered.

In general there are three methods practiced in the treatment of arrest of descent, viz., removal of the testis, abdominal reposition and orchidopexy. Szymankowski,<sup>261</sup> himself<sup>16</sup> the victim of malignancy in an inguinal testis, was a strong advocate of its therapeutic removal. Many support him in this belief.<sup>267</sup> Others urge removal of the inguinal testis only in the event of pain or other complicating factor, and still others believe that the inguinal testis should be removed<sup>7, 173</sup> after puberty if the other testis is in the scrotum. The testis within the abdomen has usually been left alone unless a hernia has necessitated

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\* Duchesne<sup>68</sup> reports the case of a boy with bilateral incomplete descent. At 16 an inguinal testis was placed in the scrotum; at 17 a right inguinal testis was similarly treated, but retracted to the external ring. At 18 spermatozoa were found in the semen. Froehlich<sup>100</sup> reports the same finding in a boy of 18 who had been operated on the year before for bilateral inguinal retention. Coley<sup>21</sup> observed spermatozoa in the ejaculation of a man of 30 after the bilateral operation. Coudray<sup>55</sup> observed a boy whose testes descended spontaneously after 11 years of age; nine years later sperm were present.

scrotum were immersed in water at the same temperature. The lowest temperature that will cause these changes he found to be 40 C. The higher temperatures required much less time to bring about the same effect. Moore and Quick<sup>193</sup> have observed these degenerative changes in the testis of guinea-pigs when exposed to increased temperature. Moore and Oslund<sup>194</sup> have also shown that following insulation of the scrotum of a ram with successive layers of woollen batting and cloth the same aspermatic condition is produced. Moore and Quick<sup>193</sup> observed a difference of 8 degrees C. between the temperature of the scrotum and abdominal cavity in guinea-pigs.

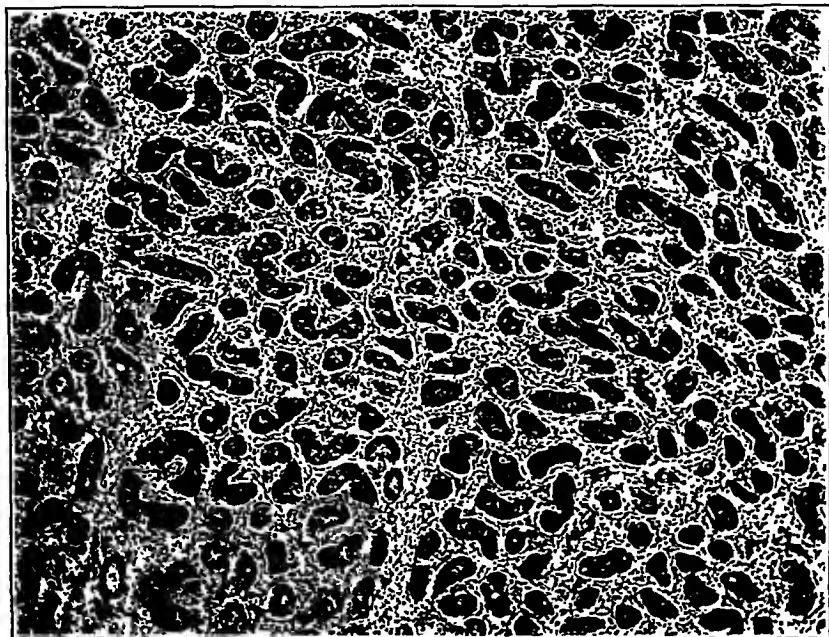


Fig. 22.—Testis of a 2 year old child.

These data would indicate that the scrotum exerts a beneficial influence on the testis through its ability to maintain a constant temperature. Whether the thermal explanation is correct or not, at least the scrotum is very necessary to the maintenance of a normal histologic picture in an otherwise normal healthy gland.

There are a few other facts that would support the heat factor as being of considerable significance. Hart<sup>123</sup> observed that elevation of the body temperature in gray mice when kept in iron cages at a temperature of 40 for five days causes atrophy of the germinal cells. It has long been known that in acute febrile diseases a degeneration of the germinal epithelium occurs. Stigler<sup>259</sup> showed that a temperature of 40.2 for four hours would cause the sperm to lose their motility.

The germinal epithelium apparently is sensitive to injury and a number of other agents can bring about its disappearance. Acute febrile

The undescended testis, therefore, should be in the scrotum before spermatogenesis occurs. Because of the occasional occurrence of late descent, the operation may well be delayed until the ninth or tenth year; not infrequently a testis that could not be palpated will come down into the canal during the first few years of life. The presence of a hernia may urge the performance of the operation at a relatively early date. It has previously been stated that the testis increases little in size until puberty. The increase in the musculature of the vas and cremaster parallels <sup>200</sup> the increase in size of the testis. He who advocates waiting <sup>44, 245</sup> until the structures are larger would jeopardize the function of the testis. I feel that the age of choice in which to do the procedure lies between the ninth and eleventh years. Only rarely will the placing of a testis into the scrotum as late as the sixteenth year be of any functional benefit. In the patient who presents himself for operation at a late date, the result can only be cosmetic.

#### OPERATIVE PROCEDURE

The modern operation of orchidopexy begins with Schüller,<sup>240</sup> It had been previously performed but with little success.<sup>1, 46, 207, 226</sup> Bevan's <sup>16, 17, 18</sup> admirable description of the procedure contains practically everything that is fundamental in the technic. Adherents of the procedure everywhere have since found that the separation of the testis from the vaginal process, the freeing of the vessels and vas deferens into the abdominal cavity, and the separation of the fascial coverings of the cord permit the mobilization of the testis. The suture of the lower portion of the vaginal tunic around the testis is not necessary to the success of the procedure.

In one particular, however, I cannot agree with Bevan. In many instances, as Bevan states, after the testis has been mobilized it may with ease be placed on the thigh several inches below the inguinal ligament. If the testis is then placed in the scrotum, one is surprised to find that in a few days it has retracted to the top of the scrotum. Bevan's purse string suture, it is true, will prevent the testis from being retracted out of the upper part of the scrotum, but this is not the physiologic position of the testis. Many believe that anchoring the testis at the radix peni accomplishes what nature had intended. However, such is not the case. Since Fukui's <sup>102, 103, 104</sup> and Moore's <sup>101, 103</sup> researches, it is apparent that the bottom of the scrotum is the physiologic position of the testis. Under the influence of cold the scrotum retracts, and on warm days the scrotum is quite pendant and the normally situated testis follows the movements of the scrotum.

I therefore believe that suture of the testis to the bottom of the scrotum is necessary, but not this alone. A suture should be run through

Reich \* has recently reported 426 testes measurements in the living by the use of calipers in 221 boys of various ages from birth to 16 years of age. A study of his measurements shows that the testis scarcely shows any definite appreciable growth before the eleventh year. Table 3 is a record of his measurements.

From these weights it is apparent that the testis increases but slowly in weight from birth to puberty. Scammon <sup>232</sup> states that the weight of the two testes at birth with their epididymides is about 2 Gm. During the first two years of life this weight is doubled, but until the thirteenth or fourteenth year the increase is very gradual, the average combined

TABLE 3.—*Measurements of Testis from Birth to Sixteen Years in 221 Boys (Reich)*

Age	No. of Cases	Left		Right	
		Length, Cm.	Breadth, Cm.	Length, Cm.	Breadth, Cm.
0-1 month.....	6	1.5	0.7	1.6	0.8
1-2 months.....	7	1.6	0.8	1.6	0.8
2-3 months.....	11	1.6	0.8	1.6	0.8
3-4 months.....	7	1.6	0.8	1.6	0.8
4-5 months.....	4	1.7	0.8	1.7	0.8
5-6 months.....	6	1.7	0.8	1.7	0.8
6-7 months.....	4	1.6	0.8	1.6	0.8
7-8 months.....	5	1.6	0.8	1.6	0.8
8-9 months.....	5	1.6	0.8	1.6	0.8
9-10 months.....	4	1.6	0.8	1.6	0.8
10-11 months.....	5	1.6	0.8	1.6	0.8
11-12 months.....	7	1.6	0.9	1.6	0.9
1-2 years.....	28	1.7	0.8	1.7	0.9
2-3 years.....	13	1.6	0.9	1.6	0.8
3-4 years.....	10	1.6	0.8	1.6	0.8
4-5 years.....	5	1.6	0.8	1.6	0.8
5-6 years.....	6	1.7	0.9	1.7	0.8
6-7 years.....	14	1.7	0.9	1.7	0.9
7-8 years.....	11	1.7	0.8	1.7	0.8
8-9 years.....	13	1.5	0.9	1.6	0.8
9-10 years.....	8	1.7	0.9	1.7	0.9
10-11 years.....	11	1.7	0.9	1.7	0.9
11-12 years.....	8	1.9	0.9	2.0	1.0
12-13 years.....	7	2.3	1.2	2.3	1.2
13-14 years.....	6	2.8	1.4	2.8	1.4
14-15 years.....	6	2.8	1.4	2.9	1.5
15-16 years.....	4	3.5	2.0	3.6	2.0

weight of the testes and epididymides then being about 4 Gm. Mita's <sup>183</sup> figures show that the sudden increase in weight occurs about the thirteenth year. In Wwedensky's <sup>208</sup> statistics this marked increase is delayed until the fifteenth year. At all events, the increase in weight from the end of the first year to the time at which a sudden increase occurs is but a gram for each testis. Reich's data show that there is practically no increase in size of the testis until the beginning of the twelfth year, and Reich states that there is no growth of the testis during the first eleven years of life.

Spangaro <sup>253</sup> studied the histologic changes in testes from birth to old age and noted the similarity between those of the new-born and the prepuberty testes. Only with the increase of weight incident to puberty

\* Reich: Testikelmessungen bei Kindern, *Jahr. f. Kinderh.* 105:290-300, 1924.



I would advocate, therefore, as a routine procedure in complete descent or maldescent of the testis early surgical intervention. The testis wherever possible should be brought to lie at the lowest portion of the scrotum. Only in a scrotal testis will the germinal epithelium develop normally. A high scrotal testis is better than one in the inguinal region or one retained within the abdomen. Abdominal reposition of the testis is preferable to vessel section. In such an event, the testis is probably better placed in the retroperitoneal space. If placed in the peritoneal cavity,\* torsion is more likely to occur.<sup>280</sup> A tender or painful testis in the inguinal area that can not be gotten into the scrotum without vessel section may as well be removed, for if replaced within the abdomen not infrequently it continues to be painful.<sup>238</sup> An abdominal testis still maintains its internal secretion; a testis with the vessels cut is functionless. Castration in the uncomplicated undescended testis is rarely indicated. One-sixteenth of a normal testis<sup>167</sup> suffices to permit the secondary sex characters to develop normally in the rabbit and guinea-pig, and man probably would do very well with one. Hypertrophy of the remaining organ, however, does not occur<sup>166</sup> after castration. Malignancy of the testis is rare, more common in the undescended than in the scrotal testis. Scrotal fixation does not diminish the possibility of malignancy. Why remove such an organ prophylactically when it is so seldom the seat of malignancy, when we fail to apply the same rule to structures in which malignancy is not unusual?

#### SUMMARY

The testes of adult dogs have been placed in the inguinal region and the peritoneal cavity. Loss of the germinal epithelium always follows. These changes are not observed in the prepuberty dog's testis when placed under similar experimental conditions. Ligation of the vas deferens does not result in atrophy of the germinal cells nor in hypertrophy of the interstitium. Section of the internal spermatic artery is followed always by diminution in size of the dog's testis and by scattered degenerative changes in the tubules; spermatogenesis still continues. Ligation of the internal spermatic artery with either the anterior or posterior group of veins in the pampiniform plexus is followed by the same change that accompanies ligation of the artery alone. Ligation of the internal spermatic artery and all the veins in the pampiniform plexus always results in total destruction of the testis. The preservation of the tunica vaginalis testis is not necessary for the development of a normal gland. Replacement of the dog's testis in the scrotum after it has been resident in the peritoneal cavity or inguinal region until most of the germinal epithelium has disappeared (only spermatogonia per-

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\* If the testis is placed in the peritoneal cavity, the vas deferens should be divided, for should gonorrheal epididymitis occur, peritonitis would follow.

tissue. Spermatogonia and Sertoli cells are present in the tubules. The average diameter of the tubules is 60 microns. The interstitial cells appear prominent and the connective tissue between the tubules is quite delicate.

In the second period from birth to 14 years, the tunica albuginea takes on a fibrous character and consists of two layers. The connective tissue between the tubules contains elastic fibers that do not become prominent, however, until 6 years of age. The epithelium of the tubules consists of nonfunctioning spermatogonia and the Sertoli cells.

During the third period beginning with the fifteenth year the tunica albuginea and corpus Highmori become thicker. The diameter of the

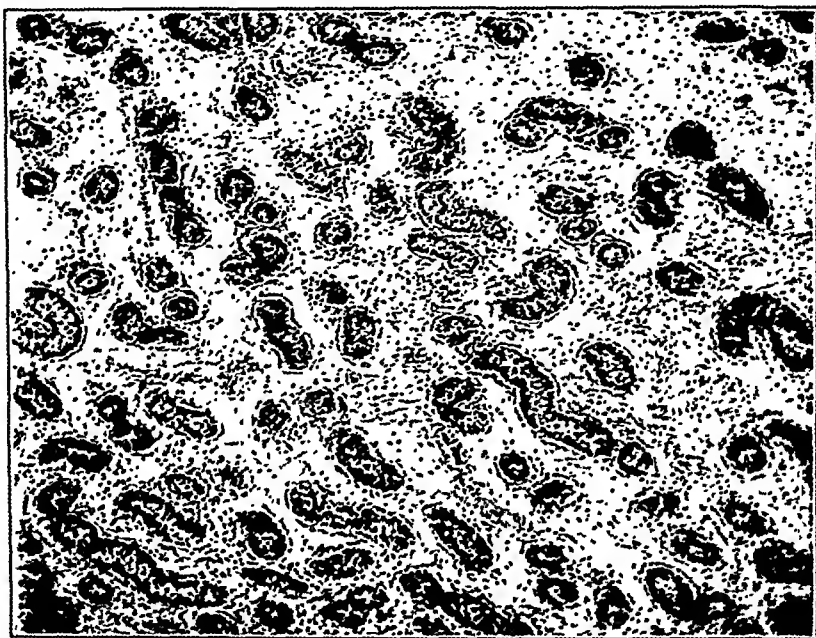


Fig. 24.—Testis of an 11 year old child; no mature germinal cells; increase in number of spermatogonia as compared with Sertoli cells.

tubules increases from 60 to 85-90 microns, and the adult germinal cells become differentiated.

It has previously been pointed out that the spermatogonia are the most resistant to injury and persist in the seminiferous tubules after transplantation of the testis from the scrotum for some time after all the other germinal cells have disappeared. In the prepuberty dog's testis in which only Sertoli cells and spermatogonia exist in the tubules, no change is observed in the histology of the organ when the gland is placed in the abdominal cavity or inguinal region under the same conditions that cause disappearance of the germinal epithelium in testes of the adult dog.

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Rasmussen<sup>215</sup> and Hansemann<sup>121</sup> noted that the germinal epithelium disappears in the hibernating woodchuck. Marshall<sup>176</sup> says that in rodents the testes go back into the abdomen after rest, and that in testes of tame rabbits in winter there is little evidence of spermatogenesis. These reports have been confirmed by others.<sup>59, 114, 166</sup>

After finding in the abdominal transplantation of the testes in rabbits that the control left in the scrotum had also slipped into the abdomen, I abandoned rodents as the subject of experiment and chose the dog whose testis like that of man is continually resident in the scrotum. I am aware that Regaud<sup>218</sup> examined the testes of rats and found spermatogenesis present at all seasons of the year, but the scrotum is not the normal location of rodents' testes and I feel that it would be hazardous to apply to a testis whose habitat is always the scrotum the same standard that obtains in a testis that can be drawn into the abdomen at will. In the human being "*ectopie en retour*" always results in atrophy. In rodents this is physiologic.

A group of animals known as Testiconda,<sup>205, 270</sup> including the elephant, walrus, seal and camel, normally have a testis in the abdomen or inguinal region. In these animals this position of the testis is compatible with fertility. In the ram, boar,<sup>9</sup> the bull, horse<sup>126, 127</sup> or dog this position of the testis as in man is associated with an atrophic condition of the testis. Hobday<sup>120</sup> states that the nearer the testis approaches the scrotum in horses, the more likely is that testis to exhibit spermatozoa.

Numerous authors state that the anatomy of the human undescended testis is normal before puberty.<sup>20, 161, 174, 252</sup> Unfortunately only few of these have been obtained for microscopic examination. However, the examination of a small number of these have been recorded and in practically every instance they have been described as normal. Felizet and Branca,<sup>86, 87, 88, 89, 93</sup> to whom we are indebted for a number of these examinations, though believing that a primary atrophy of infancy and a secondary postpuberty deterioration bring about the degenerate condition of the undescended testis, nevertheless state that the phenomena of degeneration are much less frequent in the undescended testis of the young subject than in the adult. Their examinations of undescended testes in young subjects show that a germinal epithelium represented by spermatogonia, spermatocytes and spermatids is elaborated.<sup>86, 89</sup> They believe that atrophy occurs before spermatozoa are formed. A testis that can produce spermatocytes can also produce spermatozoa and maintain a normal spermatogenesis under the proper environment as observed in scrotal replacement of abdominal testes in dogs.

Felizet and Branca<sup>86, 89</sup> in two articles on the histology of the undescended testis in the young record the examination of twenty-four undescended testes in their first paper, fourteen of which were in the

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Bezancon mentions the examination of two undescended testes in the young. One of these was an inguinal testis removed from a boy of 13. When compared with a scrotal testis of a boy of the same age removed at postmortem, Bezancon states that there was no difference and that the histology of the undescended testis was normal. He cites one other case, that of a boy of 1 year whose undescended testis was smaller than the scrotal testis, but here there was also an abnormal blood supply in that the spermatic artery arose from the aorta just above its bifurcation.

Staemmler reports the examination of three prepuberty undescended testes :

1. Left inguinal testis, age, 15; weight of descended organ, 7 Gm.; weight of undescended organ, 3 Gm.; degenerative phenomena present in the undescended testis.

2. Right inguinal testis, age 6; same weight and appearance as the descended testis.

3. Bilateral inguinal testes,  $4\frac{3}{4}$  years; "Kyrle's undeveloped testes."

A word of explanation here is necessary as to what the so-called underdeveloped testis of Kyrle<sup>154, 155, 156, 157</sup> is. Kyrle examined 110 testes in children. Eighty-six of these he found to be grossly hypoplastic and of the twenty-four, one-half were microscopically hypoplastic. Diamantopoulos<sup>67</sup> concurs in Kyrle's observation and finds that a normal testis in the young is a rare occurrence. Spangaro,<sup>253</sup> Mita<sup>183</sup> and Wwedenski's<sup>298</sup> descriptions of the normal condition in the prepuberty testis would agree with what Kyrle and Diamantopoulos describe as a hypoplastic gland. Reich states that a testis is only to be described as infantile if it fails to assume the normal growth after the eleventh year. Schultze's<sup>241</sup> findings are in agreement with those of Spangaro, Mita and Wwedenski. Voss,<sup>284</sup> using Kyrle's criteria, was able to find only seven normal testes in 117 examinations of children under 11. In thirteen boys from 12 to 20, however, the normal condition was observed in twelve, or 93.8 per cent. Voss makes the interesting comment that a hypoplastic child's testis can apparently assume the normal condition at puberty. The primary atrophy of undescended testes that Felizet and Branca<sup>80, 80</sup> recognize in infancy is apparently the so-called Kyrle's underdeveloped or hypoplastic testis, a normal finding in prepuberty testes.

The surgeon who palpates the undescended testis of the child and pronounces it atrophic commits the same error, not taking cognizance of the fact that the scrotal testis until spermatogenesis supervenes is also to palpation an "atrophic" organ.

There are a few cases on record in which sperm production or children have followed marriage after bilateral orchidopexy in the father. In

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interference. In bilateral abdominal retention, operation has been urged to preserve the secondary sexual characters under the impression that cryptorchids were not infrequently like castrates. From what has gone before, it is obvious that the ideal treatment of partial descent is fixation of the testis in the scrotum without injury to the vessels.

*Age.*—The best age at which to place the testis in the scrotum also is a matter of dispute. Most writers are agreed that the operation should be done before puberty. Brocha<sup>33</sup> states that the operation may be performed as soon as the child is diaper broke. Mixter<sup>185</sup> and Eisendrath<sup>78</sup> believe that the operation should be done at any early age. Eisendrath, however, doesn't believe that placing the testis in the scrotum favorably affects the spermatogenetic power of such a testis. Le Joly-Senoville<sup>161</sup> believes that from 14 to 16 is the proper age; Duchesne,<sup>68</sup> from 10 to 20, and Carlier,<sup>44</sup> from 17 to 25. The belief that pituitary<sup>78</sup> or thyroid<sup>108</sup> extract will encourage spontaneous descent is without foundation.

A consideration of the anatomy of the prepuberty testis and the reaction of the young dog's testis to transplantation outside the scrotum, however, indicate that the operation must be done before puberty changes supervene. Wwedenski<sup>298</sup> believes that 15 is the age of puberty. Spangaro<sup>253</sup> states that independent of race and individual difference the puberty age lies usually between the thirteenth and fifteenth years. Mita<sup>183</sup> first observed spermatogenesis in a testis of a boy of 13. Le Prince,<sup>164</sup> in a study of the time at which spermatogenesis occurs, first observed the presence of spermatozoa at 13.5 years. Crampton<sup>60</sup> studied the physiologic age in 48,000 New York high school boys and determined from the appearance of pubescence in these children that only 6 per cent were mature at the age of 12.5-13 years. Between 14.5 and 15 years, 60 per cent were mature; at 17.5-18 years, 100 per cent had reached the mature physiologic age.

Scammon<sup>233</sup> believes that even in the absence of the appearance of spermatogenesis in the young testis the changes incident to puberty may begin to occur as early as the ninth year. The reposition of the testes of young pups of from 4 to 6 months of age would also support this opinion. In the elevated testes of these dogs, though the degenerative processes observed in adult dogs did not occur, occasionally large mononucleated cells with acidophilic cytoplasm made their appearance. These probably indicate that the spermatogonia are preparing for the production of the mature germinal cells. In the testes of pups of from 2 to 3 months of age, these changes are constantly absent. As soon as spermatogenesis occurs in the young dog's testis, it becomes just as sensitive to removal from the scrotum as does the testis of the mature dog.



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the bottom of the scrotum and the testis maintained in its physiologic position for days under tension by mechanical fixation. \*

It seems strange that the testis stripped of the cremaster and all the fascial coverings should retract. The number of poor results following orchidopexy, however, indicate that it does occur. When the mobilized gland hangs freely suspended by the vas and vessels alone, retraction signifies that one or the other has brought about the elevation of the gland.\*\* Fecher<sup>85</sup> has investigated the elasticity of the vas and spermatic vessels and finds that the vessels will permit of twice as much stretching as the vas. It is physiologic for blood vessels to retract. Fecher, however, concludes that the vas is the cause of the retraction. I should infer from his experiments that the vessels being twice as elastic as the vas are much more likely to be the factor in the retraction. The greater ease with which the testis is maintained at the bottom of the scrotum after vessel section would also support this view.

In addition to lengthening of the spermatic cord by a method such as Bevan's, it has been suggested that the path the cord has to traverse can be shortened. Procedures such as those of Davison,<sup>†</sup> Wolfer<sup>206</sup> and Frangenheim<sup>90</sup> are directed toward this end. The chief increase in length that occurs, however, after division of the deep epigastric vessels or transplantation of the testis behind them is in the vas deferens and this structure is practically always long enough. The gain in length of the spermatic vessels by the maneuver is slight. Sievers<sup>247</sup> has suggested passing the testis through the obturator foramen.

If the internal spermatic artery and veins in the pampiniform plexus have to be divided to place the testis in the scrotum, atrophy of the germinal epithelium not only occurs but also of the interstitium. Such a testis is no longer a gland<sup>‡</sup> but a structure composed only of scar tissue.§ The only benefit to the patient in such a procedure over removal of the testis is the comforting feeling that there is something in the scrotal pouch.

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\* For a discussion of methods of fixation after orchidopexy, reference should be made to Sievers<sup>247</sup> and Bruskin.<sup>37</sup> Attempts at establishing an artificial syn-orchidism<sup>170, 221</sup> or fixation of the testis outside the scrotum are procedures that have nothing to recommend them.

\*\* For a discussion of results following orchidopexy, reference should be made to Bevan,<sup>19</sup> Dardel,<sup>42</sup> Goeritz,<sup>107</sup> Burkhard,<sup>43</sup> Coley,<sup>61</sup> Mixter,<sup>191, 193</sup> Caulk,<sup>44</sup> Paschen,<sup>208</sup> Brocha<sup>22</sup> and Tuffier.<sup>222</sup>

† Davison: Surg. Gynec. Obst. 12:283, 1911.

‡ The same probably obtains when the pampiniform plexus is divided in the treatment of varicocele. Ligation and section of the veins in the suprascrotal portion of the cord not infrequently includes the internal spermatic artery.<sup>91, 221, 222</sup> Ligation of the veins alone, especially if done high up near the internal ring, is compatible with a testis capable of spermatogenesis, but the testis usually is reduced in size.

§ The epididymis remains fairly normal.

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sisting) will be followed by regeneration of the mature germinal cells and normal spermatogenesis. In the adult dog only a scrotal testis is normal. The testis is very sensitive to injury and in all procedures a sufficient length of time must be allowed to intervene to preclude damage due to the manipulation alone.

Undescended testes in the human adult are practically always aspermatic. These testes, however, do elaborate the mature germinal cells, but the aberrant position of the testis does not permit of the continuance of spermatogenesis. The prepuberty testis and the testis of the new-born differ but slightly in weight and the histology is practically the same. The undescended prepuberty testis is histologically similar to the scrotal testis of the same age. If placed in the scrotum without vessel damage before puberty, the undescended testis will develop normally. Ligation of all the vessels to the testis with the exception of the artery and vein accompanying the vas deferens is followed by destruction of the testis. Scrotal fixation does not minimize the possibility of an undescended testis becoming malignant. Castration in the absence of complication is too radical a therapy in the management of undescended testes.

#### CONCLUSIONS

1. The undescended testis owes its imperfection to its position.
2. Scrotal fixation of the undescended testis in its physiologic position before the histologic changes incident to puberty occur will enable it to develop normally.

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# CARDIAC OUTPUT IN THE DOG DURING ETHER ANESTHESIA

## I. THE EFFECT OF ETHER ANESTHESIA ON THE CARDIAC OUTPUT\*

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The condition of the heart during an anesthetic is of great concern both to the surgeon and to the anesthetist. As the primary function of the heart is mechanical, in that it serves as a pump to distribute blood to the entire body, the main interest should center in the ability of the heart to continue to supply a sufficiently large amount of blood to meet the body needs. One of the main advantages of ether over chloroform anesthesia is that the former in toxic dosages causes first a paralysis of the respiratory center, which is more easily combated than is paralysis of the heart. However, this does not signify necessarily that ether has a selective action on the respiratory center, as it is known that the heart action is poor at the time of the respiratory failure. It is possible that severe injury to the circulatory system may precede paralysis of the respiratory center.

In recent years, the studies on the effects of anesthesia have centered mainly on changes in the hydrogen ion concentration and in the alkali reserve. Menten and Crile<sup>1</sup> first showed an increase in the hydrogen ion concentration during ether anesthesia. Van Slyke, Austin, Cullen<sup>2</sup> and others have studied in great detail the changes in the blood during anesthesia. Many observations on the blood pressure changes during ether anesthesia are reported. There have been no studies directed toward determining the changes in the output of the intact heart during ether anesthesia. The statements found in the literature in regard to the effect of ether on the cardiac output are based on studies on the various functions of the circulation such as blood pressure readings, or on the effect of ether on the output of the isolated heart.

There exists a difference of opinion as to the direct effect of ether on the heart, but most of the experimental evidence supports the view that it is a cardiac depressant when administered to a sufficient degree

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\* Reported in brief before the Vanderbilt Medical Society, Nashville, May, 1926.

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TABLE 1.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-Venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	$\mu$	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
5/12/26: Control; $\frac{3}{4}$ grain morphine .....	8.6	99	70	15.30	8.83	6.48	17.1	90	73.95	7.35	1,141	132.7	16.3
5/12/26: After 7 minutes ether .....	8.0	99	150	14.04	11.01	3	17.22	82	59.04	7.29	1,908	228.9	13.1
5/12/26: After additional ether .....	8.6	99	150	14.40	11.40	.3	....	..	53.4	7.30	1,947	226.4	13.0
5/12/26: Two hours after stopping ether .....	8.0	98.5	76	15.24	8.06	6.58	...	..	75.61	7.36	1,148	133.4	15.1
5/15/26, 2 p. m.: Control; $\frac{3}{4}$ grain morphine .....	8.2	101	120	13.8	6.97	6.83	15.5	94.5	62.52	....	915	111.5	7.6
5/15/26, 3:15 p. m.: After 6 minutes ether .....	8.2	101	180	11.51	8.30	3.15	17.0	68	57.2	....	1,810	221	10.1

Protocol: 5/12/26: Control study was performed after giving  $\frac{3}{4}$  grain of morphine. Dog was then given ether anesthesia through a mask for seven minutes until the eye reflexes were barely abolished, and a determination of the output was made. The ether was discontinued for a few minutes, and then the animal was again given an anesthetic for seven minutes, and another determination of the output was made. The last studies were made two hours after the ether was discontinued. The animal was quiet during all the observations.

5/15/26: Control study after giving  $\frac{3}{4}$  grain of morphine. Ether anesthesia was begun at 3:15 p. m. and determinations were made six minutes later, the eye reflexes being abolished at time the specimens of blood were obtained.

TABLE 2.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-Venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
3/15/26, 4:30 p. m.: Control study .....	10.3	100	60	14.33	8.22	6.21	53.55	57.82	.....	101.45	1,694	158.6	27
3/15/26, 10:00 p. m.: Control study .....	10.3	100	60	15.63	9.96	5.72	44.75	48.95	.....	94.0	1,644	169.6	27
3/16/26: Control study; no morphine .....	10.3	103	150	13.74	7.48	6.26	41.53	45.15	.....	99.8	1,554	154.7	10.6
3/29/26, 2:00 p. m.: Control study; $\frac{1}{2}$ grain morphine .....	10.0	99	54	15.53	9.01	6.52	39.07	45.89	.....	102.5	1,572	157.2	29
3/29/26, 4:00 p. m.: Light ether 50 minutes .....	10.0	99	150	16.81	13.06	3.75	37.75	42.29	17.07 (98%)	80	2,134	213	14
3/31/26: After 45 minutes deep anesthetic .....	9.9	99	180	14.95	10.45	4.50	.....	.....	.....	78	1,731	175	10

Protocol: Control studies on 3/15, 3/16 and 3/29/26. 3/29: determinations were made fifty minutes following the beginning of an ether anesthetic; eye reflexes were not abolished. 3/31, studies forty-five minutes following the beginning of an ether anesthetic; eye reflexes were not obtainable.

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TABLE 3.—Effect of Ether Anesthesia on the Cardiac Output and on the Hydrogen Ion Concentration

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
5/10/26: Control study; no morphine .....	14.2	102.2	100	15.26	9.84	5.42	15.43	118.37	2,184	153.8	21.84
5/10/26: After 35 minutes ether; no morphine.....	14.2	101.8	210	10.50	7.68	2.82	17.39	77.5	2,741	192.3	13.05

Protocol: 5/10/26: Trained dog; control studies made without morphine. Studies repeated thirty-five minutes following beginning of ether anesthetic; eye reflexes were abolished.

TABLE 4.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
2/13/26: Control study.....	7.7	99	80	17.37	11.78	5.59	18.53	94	71	1,270	165	15.9
2/13/26: After 30 minutes ether	7.7	99	165	17.19	13.95	3.24	.....	..	66.4	2,049	268	12.4

Protocol: 2/13/26, 7:30 p. m.: One grain morphine was given. 8:00 p. m.: Tracheotomy performed; 9:00 p. m.: control determinations; 11:00 p. m.: studies made thirty minutes following the beginning of an ether anesthetic. Eye reflexes were not abolished completely.

TABLE 5.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
2/15/26, study	7.5	98.6	72	14.97	8.42	6.55	.....	..	51.66	789	105	11
2/15/26, ether	7.5	....	108	15.32	12.79	2.53	17.92	86	51.66	2,042	272	18.9
2/15/26, ether	7.5	....	112	15.32	12.63	2.69	.....	..	54.0	2,008	268	18
2/16/26, ether	7.5	98.6	180	9.47	4.79	4.68	17.94	53	52	1,111	148	8.2
2/16/26, 1:00 a. m.: Deep ether	7.5	....	180	9.23	4.35	4.88	.....	..	53.5	1,096	146.1	6.1

Protocol: 2/15/26, 8:00 p. m., dog received 1½ grains of morphine; 9:15 p. m., the animal was quiet, control studies were made; 10:05 p. m. and 10:15 p. m., oxygen consumption of about thirty minutes' duration, eye reflexes present. The ether cone was removed between these two studies in order to determine the studies after anesthesia of 2/16, 12:45 a. m. and 1:00 a. m., studies with the animal under deep ether anesthesia of about one hour's duration, eye reflexes were abolished. Dog died about fifteen minutes after the last observation, probably due to the ether. No hemopericardium.

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TABLE 6.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
3/7/26, 5:30 p. m.: Control study	6.8	97	60	16.08	6.60	9.48	59.04	623	91.6	10
3/7/26, 8:15 p. m.: After ether anesthetic for 25 minutes	6.8	..	78	16.02	10.68	5.34	66.42	1,214	183	16
3/7/26, 10:15 p. m.: Two hours after anesthetic was stopped	6.8	..	65	16.14	8.04	8.10	68.26	813	124	13

Protocol: 3/7/26: Healthy young dog. At 4:45 p. m., he received  $\frac{1}{2}$  grain of morphine; 5:15 p. m., tracheotomy was performed; 5:40 p. m., control studies were made; 8:15 p. m., determinations made after animal had received ether through the tracheotomy tube for twenty-five minutes, eye reflexes not completely abolished; 10:15 p. m., two hours after the anesthetic was stopped, studies were repeated.

TABLE 7.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/1/26, 2:00 p. m.: Control study; 1 grain morphine	9.1	100.4	65	13.95	6.2	7.75	15.32	91	77.49	999	110	15.4
6/1/26, 4:30 p. m.: After 40 minutes anesthesia	9.1	98.4	130	11.92	6.79	5.13	.....	..	70.11	1,367	150.2	10.5
6/1/26, 8:15 p. m.: Four hours after anesthesia and operation	9.1	98	160	14.88	9.12	5.76	.....	..	79.33	1,377	151.3	9.2

Protocol: 6/1/26: At 1:30 p. m., 1 grain morphine was administered; 2:00 p. m., the dog was completely quiet, and control study was made; 4:30 p. m., completion of forty minutes ether anesthetic; eye reflexes were abolished; 4:35 p. m., abdominal incision, terminal aorta isolated but not ligated, abdomen was closed; 8:45 p. m., four hours following completion of anesthetic, dog able to walk around but unsteady. Third determinations were made.

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TABLE 8.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
3/25/26; Control study; no morphine .....	16	102.6	95	18.81	13.71	5.10	19.20	98	115.2	2,837	146	24.6
Two hours later; Control study; no morphine .....	16	102.6	96	18.70	13.12	5.58	19.41	96	115.0	2,061	129	21.4
4/8/26; Control study; no morphine .....	15.5	102.2	100	15.74	9.45	6.29	.....	..	140.2	2,213	143	22.1
4/23/26; Control study; no morphine .....	14.3	104	130	15.50	9.54	5.96	17.6	88	140	2,349	164	18
4/23/26; After 1 hour light ether anesthesia .....	14.3	104	200	13.59	11.59	2.0	.....	..	118.1	5,845	409	29

Protocol: Control studies on trained dog without morphine on 3/25/26, 4/8, and 4/29. The animal was given an ether anesthetic for one hour following the last control study, the eye reflex not being abolished, and the cardiac output determined.

TABLE 9.—Effect on Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/12/26, 2:30 p. m.: Control study .....	14	103	84	15.8	10.96	4.84	41.59	43.99	.....	151.29	3,126	223.3	37.2
5:00 p. m.: After 2 hours ether anesthetic .....	14	102.6	240	15.8	13.36	2.44	23.33	24.66	19.39 (82%)	125.46	5,142	367	21.4

Protocol: 6/12/26: Trained dog, no morphine was used; at 2:30 p. m., control determinations were made; at 3:00 p. m., ether anesthetic was begun. The degree of anesthesia varied, eye reflexes were abolished several times. Specimens of blood were taken at 5:00 p. m., after two hours of anesthesia, the eye reflexes being barely obtainable.

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TABLE 10.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/10/25, 4:30 p. m.: Control study .....	13.2	100.4	48	15.70	7.73	7.97	41.45	45.50	17.18 (91%)	88.56	1,111	84.2	23.1
5:30 p. m.: After 35 minutes ether anesthesia .....	13.2	100	118	16.41	12.01	4.40	38.74	41.85	.....	84.87	1,929	146	16.3

Protocol: 6/10/26: At 3:30 p. m., 1 grain of morphine was given; at 4:30 p. m., the dog was quiet, and control determinations were made; at 4:55 p. m., ether anesthesia was begun; at 5:30 p. m., cardiac output was determined, the eye reflexes not being obtainable when specimens of blood were drawn.

TABLE 11.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/8/26, 3:40 p. m.: Control study .....	9.8	99.5	60	15.98	9.65	6.32	38.78	41.36	.....	92.2	1,459	149	24.3
4:50 p. m.: After 30 minutes ether anesthesia .....	9.8	97.6	132	16.53	13.0	3.53	39.05	40.82	17.47 (95%)	92.3	2,771	282.8	21

Protocol: 6/8/26: Dog which had been used previously in studying the effect of a digitalis preparation on the cardiac output was used; at 2:30 p. m., 1 grain of morphine was given; at 3:40 p. m., experiment was performed; at 4:50 p. m. specimens of blood were taken after ether anesthesia for thirty minutes, eye reflexes not being abolished.

for "surgical anesthesia." Cattell<sup>3</sup> studied the effect of ether anesthesia on the blood pressure, on the heart volume of intact cats and on the contractions of the isolated cold blooded heart. He stated:

Observations on the heart volume of intact cats, and on the contractions of the isolated cold blooded heart, together with deductions from blood pressure records, show that the administration of ether, from its very beginning, results in a depression of the heart and a decrease in its output, which is sufficient to account for the fall in pressure in both the normal and the shocked animals.

The literature on the effects of ether on the circulatory system was reviewed thoroughly by Cattell (1923) and was summarized as follows:

The experimental evidence briefly summarized above strongly favors the assumption that ether, in the concentrations present in ordinary anesthesia, causes a decrease in the efficiency of the heart, which might account for any fall in arterial pressure occurring under ether anesthesia.

Vernon<sup>4</sup> perfused the isolated turtle heart with Ringer's solution which contained ether and found that the extent of the contractions were reduced when the concentration of ether exceeded 0.10 per cent. Nicloux<sup>5</sup> found that the average amount of ether present in the blood in deep anesthesia varied from 0.13 to 0.15 per cent. Storm Van Leeuwen<sup>6</sup> found that the eye reflexes were abolished when the percentage of ether in the blood by weight was 0.19. It is difficult to make deductions from the figures for ether content reported by different observers, as there is a great deal of discrepancy in the results. McWilliams,<sup>7</sup> experimenting on cats, found a drop in blood pressure, together with a decrease in the functional activity of the heart, when ether was administered until the corneal reflex disappeared. Cushny<sup>8</sup> states that ether causes the heart of the frog and of mammals to beat more slowly and weakly, and at the same time causes the heart to undergo a certain amount of dilatation.

In spite of the fact that most of the experimental evidence indicates that ether has a depressing effect on the heart, there are those who believe that ether acts as a cardiac stimulant. Gwathmey<sup>9</sup> states:

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4. Vernon: J. Physiol. 41:194, 1910.

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6. Storm Van Leeuwen: Arch. f. d. ges. Physiol. 165:594, 1916.

7. McWilliams: Brit. M. J. 2:831, 1899.

8. Cushny: *Pharmacology and Therapeutics or The Action of Drugs*, Philadelphia and New York, Lea & Febiger, 1924.

9. Gwathmey: *Anesthesia*, ed. 2, rev., New York and London, the Macmillan Co., 1924.

TABLE 12.—Showing the Effect of (1) Deep Ether Anesthesia and (2) Trauma to Intestines on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
2/5/26, 11:30 a. m.: Control study	10	99	70	13.56	14.51	4.05	20.25	92	70.1	1,730	173	24.7
2/5/26, 1:30 p. m.: Deep anesthesia	10	..	180	11.92	5.41	6.51	19.12	62	66.4	1,020	102	5.7
2/5/26, 5:30 p. m.: After trauma to intestines	10	..	200	16.93	10.16	6.74	19.14	80	66	975 (?)	97.5	4.9

Protocol: 2/5/26: At 10:30 a. m.,  $\frac{1}{4}$  grains of morphine was administered; at 11:00 a. m., tracheotomy was performed; at 11:30 a. m., the animal was quiet, and control studies were made; at 1:00 p. m., ether anesthesia was begun; the dog became deeply anesthetized (stopped breathing once), and specimens of blood were drawn at 1:30 p. m.; at 5:30 p. m., four hours following the production of a great deal of trauma to the small intestines, the cardiac output was determined. The animal died shortly afterward.

TABLE 13.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/18/26, 3:30 p. m.: Control study	10	101.6	50	16.9	12.31	4.58	36.18	38.99	73.8	1,611	161	32
5:00 p. m.: After 20 minutes anesthetic	10	102	120	17.64	15.83	1.78	35.78	36.04	84.9	4,770	477	40

Protocol: 6/18/26: At 2:15 p. m., 1 grain of morphine was administered; at 3:00 p. m., tracheotomy was performed; at 3:30 p. m., control determinations were made; at 4:40 p. m., ether anesthetic was begun; at 5:00 p. m., eye reflexes being barely obtainable, specimens of blood were drawn.

Ether acts as a direct heart stimulant during the early stages of its administration, and when, during the course of deeper narcosis, the subject is allowed to return to a lighter degree, the pulse is accelerated, and the blood pressure is slightly raised or remains constant. Ether becomes a cardiac depressant only in the later stages of anesthesia, or when a toxic amount is employed.

Muns<sup>10</sup> studied the effect of ether anesthesia on the blood pressure in experimental animals. He reported a rise of blood pressure in half of the animals, whereas there was a fall in the other half. Richardson stated: "Ether, like gas oxygen, drives up the blood pressure; but to a less extent, if properly given. Ether is a cardiac stimulant of more even action." Cattell<sup>11</sup> found that the inhalation of strong ether resulted in a sudden temporary drop in arterial pressure which returned almost to the original level by the time that the eye reflexes were abolished.

The present study was undertaken for the purpose of studying the effect of ether anesthesia on the cardiac output of the intact heart of the normal dog.

#### METHODS

Dogs were used in all of the experiments. The animals varied in weight from 6 to 18 kilograms. Six of the experiments were performed on trained animals. Dogs, which had been given morphine (usually .06 Gm.) about one hour before the control determinations, were used in the remaining experiments. Marshall<sup>12</sup> and Blalock, Harrison and Wilson<sup>13</sup> have found that morphine does not alter appreciably the output of the heart. Several recent experiments have indicated that the cardiac output is diminished during the first thirty minutes after the giving of a large dose of the drug.

After the control determinations had been made, ether was administered through an open cone or through a catheter placed loosely in the tracheotomy tube. An attempt was made to obtain anesthesia of sufficient depth barely to abolish the lid reflex. This was rather difficult to do at times, due to the fact that the dog's condition changes quickly under an anesthetic. Other signs which were noted in determining the depth of the anesthetic included general relaxation, color of mucous membranes and the quality of the pulse. When the desired condition was obtained, specimens of blood were drawn with the ether cone in place, and the oxygen consumption was determined immediately after the cone was removed.

The oxygen consumption was determined by means of a Benedict spirometer with the graphic recording device. The animal was connected to the spirometer either by means of a tube placed in the trachea or by the use of an especially constructed mask which was fitted tightly over the mouth. The oxygen consumption was not determined at the same time that the ether was administered. After

10. Muns, W. E.: *Am. J. Surg. (anesthesia supplement)* 31:113 (Oct.) 1917.

11. Cattell, McKen: *Studies in Experimental Traumatic Shock; Action of Ether on Circulation in Traumatic Shock*, *Arch. Surg.* 6:83 (Jan.) 1923.

12. Marshall, E. K.: *J. Physiol.* 72:192, 1925.

13. Blalock, A.; Harrison, T. R., and Wilson, C. P.: *An Experimental Study in the Effects on the Circulation and Respiration of Morphinated Dogs*, *Arch. Surg.* 13:81 (July) 1926.

TABLE 14.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/19/26, 12:10 p. m.: Control study; ¼ grain morphine....	9.7	100	68	22.42	12.64	9.78	36.61	42.17	73.8	755	78	11
1:45 p. m.: Second control study .....	9.7	102	48	22.54	13.12	9.42	37.12	43.12	73.8	783	81	16
2:50 p. m.: Very deep anesthesia for 35 minutes.....	9.7	101	168	23.38	12.52	10.86	27.39	32.68	51.7	414	43	2.4
4:05 p. m.: Anesthesia for 35 minutes .....	9.7	101	160	23.14	17.65	5.49	23.32	26.71	73.8	1,344	139	8.4

Protocol: 6/19/26: At 11:30 a. m., ¼ grain of morphine was administered; at 12:10 p. m., control studies were made; at 1:45 p. m., second control studies were made; at 2:17 p. m., ether anesthesia was begun; at 2:50 p. m., animal was deeply under anesthetic, eye reflexes were abolished, stopped breathing just at time specimens of blood were drawn. Eye reflexes were present almost up to time animal stopped breathing. Animal revived. At 3:30 p. m., anesthetic was resumed; animal stopped breathing once, but eye reflexes were present at 4:00 p. m., when specimens of blood were taken. Animal well relaxed at time.

TABLE 15.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
3/24/26; Control study; no morphine .....	18.1	102	150	23.4	16.83	6.57	41.32	46.30	.....	151.3	2,303	127.2	15
6/21/26, 4:00 p. m.: Control study; no morphine.....	17.8	102	120	19.27	12.96	6.31	35.64	39.42	.....	169.7	2,689	151.1	22
6/21/26, 5:15 p. m.: After 40 minutes ether .....	17.8	102	175	9.36	6.42	3.46	35.10	38.07	21.22 (40%)	118.1	3,413	192	19

Protocol: 3/24/26: Elderly trained dog; no morphine, control determinations. 6/21/26: At 4:00 p. m., control study was made, no morphine was given. At 4:25 p. m., ether anesthesia was begun. The eye reflexes were never abolished, but in an attempt to do so, marked cyanosis of the mucous membranes developed. Specimens of blood were taken forty-five minutes after the anesthetic was begun, with dog deeply anesthetized at the time.

the ether cone had been removed, the attachment to the spirometer was made immediately, and the oxygen consumed during the first several minutes was determined. Since the animals were rather deeply anesthetized, and since the changes in oxygen consumption were small, it is thought that little error was introduced by this method.

Specimens of blood were withdrawn while the animal was breathing ether. Arterial blood was obtained by puncture of the left ventricle or the femoral artery; venous blood, by puncture of the right ventricle. The usual precautions against contact with air were followed. The blood gas determinations were made on the Van Slyke-Neill<sup>14</sup> manometric apparatus. The method of Austin<sup>15</sup> for determining the carbon dioxide content in the presence of ether was employed. No difficulties were encountered in obtaining duplicate readings for oxygen content in specimens of blood before and after the addition of small amounts of ether, and it is thought that the values for oxygen content in this study are absolute. Nicloux<sup>5</sup> and, later, Ronzoni<sup>16</sup> have shown that the amount of ether in the arterial blood remains higher than that in the venous blood, as long as ether of the same concentration is being administered. Since the specimens of blood in the present experiments were taken while the animals were breathing ether, it is thought that any errors in the oxygen content determinations which might be ascribed to ether would tend to increase the arteriovenous oxygen content difference rather than to diminish it, as was found.

The hydrogen ion determinations were made according to the method of Hastings and Sendroy.<sup>17</sup> The circulatory minute volume was calculated from the

$$\frac{\text{Cc. O}_2 \text{ consumed per minute}}{\text{Amount O}_2 \text{ taken up in lungs by 1 cc. of blood}} = \frac{\text{Number of cubic centimeters of blood flowing through the lungs per minute}}{\text{Cc. O}_2 \text{ consumed per minute}}$$

## RESULTS

*Control Period.*—The animals were quiet while the control studies were being made. The respiratory rate and depth varied in the different animals, but were regular in the same animal in most instances. The pulse rate was slow in the animals which were given morphine. The specimens of arterial and of venous blood were normally saturated with oxygen. The cardiac output per kilogram of body weight varied little for the same animal on different dates, but there was a rather wide variation for the different animals. In general, it may be said that this figure for the large dogs is about one hundred and thirty-five cubic centimeters per kilogram of body weight, while that for the smaller dogs is about one hundred and fifty cubic centimeters per kilogram.

*Anesthetic Period.*—The animals became restless immediately and struggled when the ether was applied. The respirations became more rapid and deeper. No studies were made during the period of excitement. The amount of ether which is necessary for producing third stage

14. Van Slyke, D. D., and Neill, J. M.: *J. Biol. Chem.* **61**:523 (Sept.) 1924.

15. Austin, J. H.: *J. Biol. Chem.* **61**:345 (Sept.) 1924.

16. Ronzoni, Ette: *J. Biol. Chem.* **57**:761 (Oct.) 1923.

17. Hastings and Sendroy: *J. Biol. Chem.* **61**:695 (Oct.) 1924

Fick formula.

TABLE 14.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/19/26, 12:10 p. m.: Control study; $\frac{1}{2}$ grain morphine....	9.7	100	68	22.42	12.64	9.78	36.61	42.17	73.8	755	78	11
1:45 p. m.: Second control study .....	9.7	102	48	22.54	13.12	9.42	37.12	43.12	73.8	783	81	16
2:50 p. m.: Very deep anesthesia for 35 minutes.....	9.7	101	169	23.38	12.62	10.86	27.39	32.68	51.7	414	43	2.4
4:05 p. m.: Anesthesia for 35 minutes .....	9.7	101	160	23.14	17.65	5.49	23.32	26.71	73.8	1,344	139	8.4

Protocol: 6/19/26: At 11:30 a. m.,  $\frac{1}{2}$  grain of morphine was administered; at 12:10 p. m., control studies were made; at 1:45 p. m., second control studies were made; at 2:17 p. m., ether anesthesia was begun; at 2:50 p. m., animal was deeply under anesthetic, eye reflexes were abolished, stopped breathing just at time specimens of blood were drawn. Eye reflexes were present almost up to time animal stopped breathing. Animal revived. At 3:30 p. m., anesthetic was resumed; animal stopped breathing once, but eye reflexes were present at 4:00 p. m., when specimens of blood were taken. Animal well relaxed at time.

TABLE 15.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
3/24/26: Control study; no morphine .....	18.1	102	160	23.4	16.83	6.57	41.32	46.30	.....	151.3	2,303	127.2	15
6/21/26, 4:00 p. m.: Control study; no morphine.....	17.8	102	120	19.27	12.96	6.31	35.64	39.42	.....	169.7	2,689	151.1	22
6/21/26, 5:15 p. m.: After 40 minutes ether .....	17.8	102	175	9.86	6.42	3.46	35.10	38.07	21.22 (46%)	118.1	3,413	192	19

Protocol: 3/24/26: Elderly trained dog; no morphine, control determinations. 6/21/26: At 4:00 p. m., control study was made, no morphine was given. At 4:25 p. m., ether anesthesia was begun. The eye reflexes were never abolished, but in an attempt to do so, marked cyanosis of the mucous membranes developed. Specimens of blood were taken forty-five minutes after the anesthetic was begun, with dog deeply anesthetized at the time.

anesthesia varies greatly in dogs just as it does in man. The time intervals separating the beginning of the anesthetic and the drawing of the specimens of blood are given in the protocols of the experiments (tables 1 to 20). This interval was varied intentionally, but in all instances sufficient time was allowed for the animal to become well relaxed. Usually the respiratory rate and depth were decreased as compared to that in the control period. The pulse rate was accelerated in all

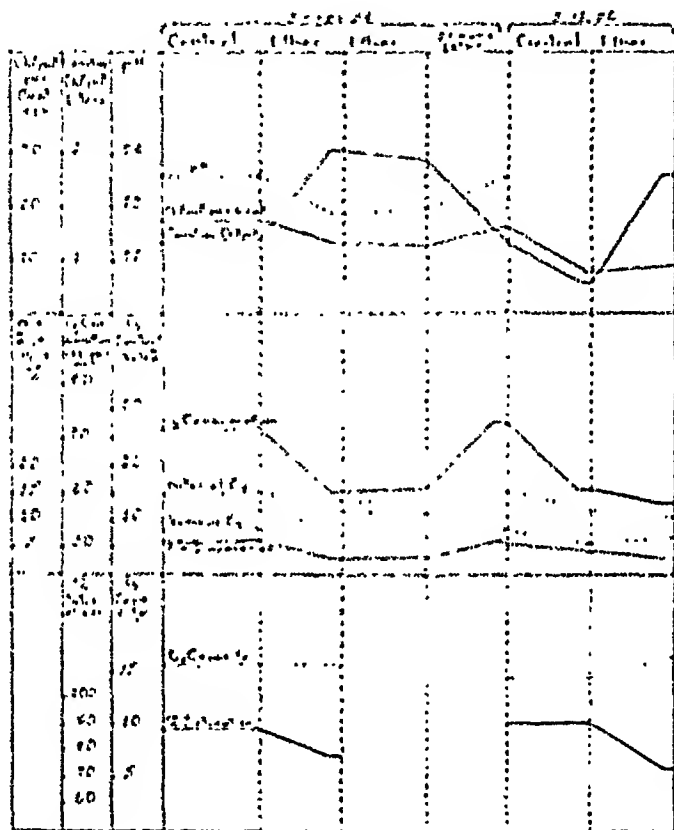


Chart 1.—This chart illustrates a typical experiment. During the anesthetic period, it is seen that the cardiac output increases, the  $p_{50}$  falls, the arterial and venous oxygen contents approach each other, the oxygen consumption is slightly decreased, the percentage saturation of the arterial blood falls while the oxygen capacity remains about the same.

Time relations are neglected in this chart. The various functions are drawn as if constant at the time of puncture. The drawings are purely schematic.

instances, the most marked increase being found in the animals deeply anesthetized. The temperature readings showed no change during a short anesthetic, but prolonged anesthesia was accompanied by a fall of one or more degrees Fahrenheit. In an attempt to anesthetize deeply several of the animals, it was found that a toxic dose of ether was necessary to abolish completely the lid reflex. This was attempted several



TABLE 16.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
5/25/26, 8:15 a. m.: Control study	10.5	102	90	19.16	13.55	5.61	34.46	37.72	103.3	1,841	175	20
5/25/26, 4 p. m.: After ether for 17 minutes	10.5	102	215	20.60	16.69	3.91	24.44	28.08	99.6	2,547	242	12
5/26/26, 4 p. m.: Control study	10.5	101.6	108	19.11	12.62	6.49	.....	.....	118.1	1,820	173	17

Protocol: 5/25/26: Healthy dog. At 8:15 a. m., control determinations were made without morphine. An attempt was then made to anesthetize the dog by giving ether and cotton seed oil per rectum. This was unsuccessful. At 3:45 p. m., ether by mask was given for seventeen minutes before specimens of blood were taken, eye reflexes being barely obtainable. 5/26, 4:00 p. m., control study without morphine.

TABLE 17.—Effect of Ether Anesthesia on the Cardiac Output

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	pH	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/26/26, 5 p. m.: Control study; 1/4 grain morphine	11	99	48	19.89	11.65	5.24	41.18	44.15	7.35	70.1	1,338	122	28
6/26/26, 5:50 p. m.: After ether for 15 minutes	11	98.6	155	17.25	10.11	7.14	34.43	39.56	7.27	62.7	877	80	5.7
6/27/26, 3 p. m.: After ether for 25 minutes	11	98	160	12.72	6.42	6.30	29.75	36.05	7.25	77.5	1,230	112	7.7

Protocol: 6/26/26: At 4:00 p. m., 1/4 grain of morphine was given. At 5:00 p. m., control study was made. No food had been taken for previous twenty-four hours. At 5:35 p. m., ether anesthesia was begun. At 5:50 p. m., determinations were made, eye reflexes being abolished completely; mucous membranes were rather blue in color.  
6/27/26: At 2:40 p. m., ether anesthesia was begun. At 3:00 p. m., determinations were made, eye reflexes being abolished completely.

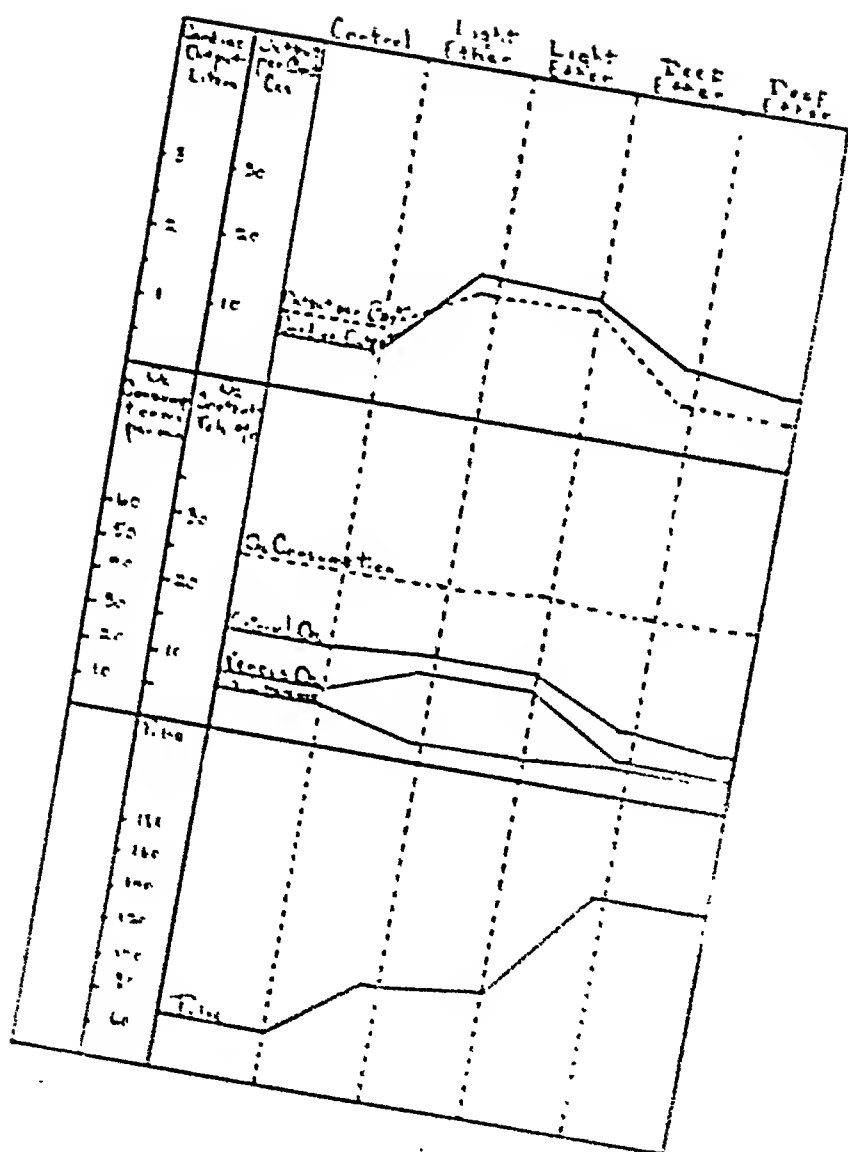


TABLE 18.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
6/28/26, 3 p. m.: Control study; 1 grain morphine...	13.3	99.4	50	15.58	10.11	5.47	35.78	40.37	7.42	1,603	120	32
3:55 p. m.: After 15 minutes anesthesia	13.3	99	120	15.58	12.72	2.86	35.37	37.53	7.37	2,742	206	23

Protocol: 6/28/26: At 2:00 p. m., 1 grain of morphine was given. At 3:20 p. m., control specimens of blood were drawn; animal was quiet. At 3:40 p. m., ether anesthetic was begun. Determinations were made fifteen minutes later, eye reflexes being abolished completely

TABLE 19.—*Effect of Ether Anesthesia on the Cardiac Output*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
7/19/26, 3 p. m.: Control study; ¾ grain morphine.....	13.5	102	60	8.46	3.90	4.56	39.16	42.64	97.2	2,132	158	35.5
7/19/26, 3:50 p. m.: After ether for 35 minutes .....	13.5	101.6	120	8.72	6.27	2.45	39.02	42.24	86.4	3,527	266	29.3

Protocol: 7/19/26: At 2:00 p. m., ¾ grain of morphine was given. At 3:00 p. m., animal was quiet, and control determinations were made. At 3:15 p. m., giving of ether anesthetic was begun. Specimens of blood were drawn at 3:50 p. m., after thirty-five minutes of anesthesia, eye reflexes being abolished at times.



# EXPERIMENTAL CHRONIC DUODENAL OBSTRUCTION

## I. TECHNIC AND PHYSIOLOGY \*

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There is a growing tendency on the part of clinicians to believe that many obscure and indefinite symptoms are due to the absorption of toxins from the intestinal tract. It is on this hypothesis that high colonic irrigations, bacterial implantations, etc., have been recommended in certain diseases. In addition, some of the more serious conditions, such as pernicious anemia, have been attributed to intestinal intoxication. Though the belief that these hypothetical toxins are produced in the intestinal tract has been prevalent for years, little direct evidence has been brought forward to support the idea. It was in the hope that we might learn something more definite that the following experiments were conducted.

Since the symptoms and diseases that have been attributed to the absorption of toxins from the intestinal tract are characterized by their chronicity, we produced and studied experimental lesions existing for a prolonged period. In our first study<sup>1</sup> we endeavored to confirm the observations of Pawlow and his co-workers,<sup>2</sup> Fischler<sup>3</sup> and others, that dogs with Eck fistulas, kept on an exclusive meat diet, developed symptoms of intoxication. However, in a series of dogs with Eck fistulas which we kept on a similar diet, no such symptoms were observed. It was concluded from these experiments that the occurrence of symptoms was too irregular for systematic study. In addition, the liver function of these dogs was tested according to the dye method described by Rosenthal.<sup>4</sup> Our results indicated that there was no impair-

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\* From the Departments of Pathology and Surgery, College of Physicians and Surgeons, Columbia University.

\* This work was aided by a grant from the Eli Lilly Company.

1. Berg, B. N.; Cone, W. V., and Jobling, J. W.: Phenoltetrachlorphthalein Test of Liver Function in Eck Fistula Dogs Kept Upon a Meat Diet, *Proc. Soc. Exper. Biol. and Med.* **23**:81, 1925.

2. Halin, M.; Massen, O.; Neneki, M., and Pawlow, J.: Die Eck'sche Fistel zwischen der unteren hohlvene und der Pfortader und ihre Folgen für den Organismus, *Arch. f. Exper. Path. u. Pharmacol.* **32**:161 (Sept. 11) 1893.

3. Fischler, F.: Über die Fleischintoxikation bei Tieren mit Eck'scher Fistel, *Deutsche Arch. f. Klin. Med.* **104**:300 (Nov. 7) 1911.

4. Rosenthal, S. M.: An Improved Method for Using Phenoltetrachlorphthalein as a Liver Function Test, *J. Pharmacol. & Exper. Therap.* **19**:385 (June) 1922.



ileus in man was due to mechanical pressure at the duodenojejunal flexure, and reproduced the condition in dogs by narrowing the lumen of the duodenum with a free, narrow strip of fascia. They fixed the duodenum to the costal arch at the site of the obstruction.

In order to produce conditions that were favorable for the study of the effects of prolonged duodenal stasis in dogs, a method was employed which we subsequently learned was similar to that adopted by Koennecke and Meyer in their work. We believe, however, that our method has the following advantages: By the use of a wide fascial flap attached by a broad pedicle to the posterior sheath of the rectus muscle, instead of a free, narrow, fascial strip, the blood supply of the obstructing band is insured; the obstruction lasts longer, and the danger of the band cutting through the intestine is diminished.

#### TECHNIC

Under ether anesthesia and with strict asepsis, a right rectus muscle-splitting incision is made. The posterior sheath, including the parietal peritoneum is incised close to the midline, and a rectangular fascial flap, about 4.5 by 6 cm., is made; usually some of the transversalis muscle is included. The size of the flap varies with the diameter of the duodenum. The latter is mobilized, and a segment about 15 cm. from the pylorus is chosen for the site of the obstruction, which varies with the length of the duodenum. An incision equal in size to the width of the flap is made in the mesentery close to the attachment of the duodenum. The flap is pulled through this opening, and five mattress sutures are introduced at the margin and near the base. The distance between the two limbs of the sutures is approximately one and one-half times the diameter of the duodenum. As the sutures are tightened, a closed forceps is introduced between them and the intestine, in order to avoid interference with the blood supply. If at a succeeding exploratory operation the obstruction is deemed inadequate, the fascial band can be tightened by taking a reef in it, a series of interrupted sutures being used. The peritoneum and fascia are closed by a continuous suture and the skin by a subcuticular suture. Silk is used throughout. For the first few days after the establishment of the obstruction, the dogs are kept on a fluid diet after which they are given a liberal amount of cooked chopped meat, bread and bone ash.

#### EXPERIMENTAL RESULTS

The foregoing method of producing a chronic duodenal obstruction in the dog was successful in twelve of fifteen attempts. Partial occlusion of the duodenum at the site of the obstruction, and dilatation and hypertrophy proximal to the obstruction were found at exploratory laparotomy and at autopsy.

While it was difficult to determine accurately the amount of dilatation due to changes in the tonus of the duodenum, it was found convenient, for tabulation and discussion, to adopt, as a rough measure, the notation given in the accompanying table.





pyloric insufficiency and reflux into the stomach. Ratkoćzi's description of so-called chronic "intermittent stenosis" of the duodenum contained many features comparable to some of our experimental observations.

In experimental obstruction of the duodenum, the only reports of fluoroscopic examinations that we found recorded were those of Koennecke and Meyer,<sup>10</sup> who correlated their clinical with their experimental observations. They stressed the hypermotility of the stomach and duodenum in the presence of experimental stenosis and noted that section of the vagus had only a transitory effect on gastric tonus after the obstruction had been established for a prolonged period. Occasionally, they identified deep peristaltic waves which originated in the stomach and progressed over the duodenum in contrast to the to-and-fro movements of the duodenum. However, they did not recognize any rhythmic relation between antral, pyloric and duodenal activity.

#### METHOD

In order to study the degree of stasis and alterations in the peristaltic activity of the stomach and the duodenum in the presence of a prolonged subacute obstruction of the latter, fluoroscopic examinations were made with the aid of an opaque meal. Seven dogs were examined. Three separate series of observations were made on each dog, with intervals of from one to two weeks between each examination. The obstructions had existed from 115 to 173 days when the first fluoroscopic observations were made. Eight ounces of a suspension of barium sulphate was given to the dogs by stomach tube. They received no food eighteen hours before the examination. Observations were made in the following manner: immediately, at the end of one hour, two hours, three and one-half hours, and five hours (in only two series). The fixation of the duodenum to the anterior abdominal wall facilitated accurate study, and the site of the obstruction was readily recognized. There was no evidence of kinking below the obstruction.

#### MOTILITY

In the normal dog, fluoroscopic examination is unsatisfactory for the observation of the motor relationship between the duodenum, pyloric sphincter and antrum. However, in the presence of an obstruction of the duodenum, we found that the accentuation of the contractions and the delayed motility enabled us to distinguish, simultaneously, the activity of each. We observed a cycle that was suggestive of one described by Wheelon and Thomas<sup>14</sup> in the normal dog, but which differed in certain respects.

As soon as enough barium had passed through the pylorus, the duodenum appeared as a long, sausage-shaped structure, limited above by the pyloric sphincter and below by the obstruction. The degree of dilatation varied; in some dogs the duodenum was many times its normal

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14. Wheelon, H., and Thomas, J. E.: Observations on the Motility of the Duodenum and the Relation of Duodenal Activity to that of the Pars Pylorica, *Am. J. Physiol.* 59:72 (Feb.) 1922.

ascribed great importance to carbon dioxide as a regulator of the cardiac output. Boothby<sup>21</sup> first suggested that hydrogen ion concentration regulated the output of the heart. Douglas and Haldane<sup>22</sup> were led to the same conclusion as a result of studies on man. Means<sup>23</sup> stated that he thought it likely that the hydrogen ion concentration regulated the output of the heart. Harrison, Wilson and Blalock<sup>24</sup> have shown that an increase in the hydrogen ion concentration is associated with an increased cardiac output, and that a decreased hydrogen ion concentration is associated with a decreased output. The administration of an ether anesthetic in the present studies was accompanied by an increase in the hydrogen ion concentration and usually by an increase in the cardiac output.

If the elevated hydrogen ion concentration is a factor in increasing the output of the heart in ether anesthesia, it is possible that it is due to the capillary dilatation which it causes. Fleisch<sup>25</sup> found that acid causes a peripheral dilatation, and that, other factors remaining the same, this results in a more rapid filling of the heart in diastole with an increased output. Eppinger<sup>26</sup> believes that the increase in the cardiac output during attacks of "cardiac asthma" is due to diminished peripheral resistance. The same interpretation is given by Harrison, Dock and Holman<sup>27</sup> in explaining the elevated output in dogs with arterio-venous fistulae. The experiments of Cattell<sup>28</sup> do not support the view that ether causes a peripheral dilatation. He stated:

Determinations of leg volume with a plethysmograph, perfusion rate measurements, and results obtained by the injection of ether directly into the circulation, together with the form of blood pressure curves, indicate that ether causes a contraction of the peripheral vessels.

No observations on the peripheral circulation were made in this study.

Patterson<sup>29</sup> found that carbon dioxide alone depresses all of the functions of the isolated heart, but that the combined effect of carbon dioxide and epinephrine resulted in more rapid and stronger contractions and more rapid relaxation, and also lengthening of the diastolic filling. Cannon and Corrasco-Formiguera<sup>20</sup> stated that asphyxia increases the

21. Boothby, W. M.: *Am. J. Physiol.* **37**:383, 1915.

22. Douglas, G. G., and Haldane, J. S.: *J. Physiol.* **56**:69 (Feb.) 1922.

23. Means, J. H.: *Dyspnoea, Medicine*, **3**:309 (Aug.) 1924.

24. Blalock, A.; Harrison, T. R., and Wilson, C. P.: *An Experimental Study in the Effects on the Circulation and Respiration of Morphinized Dogs*, *Arch. Surg.* **13**:81 (July) 1926; *J. Clin. Investigation* **1**:547 (Aug.) 1925.

25. Fleisch, A.: *Ztschr. f. allg. Physiol.* **19**:269, 1921.

26. Eppinger, H.: *Das Asthma Cardiale*, Berlin, 1924.

27. Harrison, T. R.; Dock, W., and Holman, E.: *Heart* **11**:337 (Dec.) 1924.

28. Patterson, A. W.: *Proc. Roy. Soc., ser. B.* **88**:371, 1915.

29. Cannon, W. B., and Corrasco-Formiguera, R.: *Am. J. Physiol.* **61**:215 (July) 1922.

the barium appeared below the obstruction in a continuous thin stream, throughout the cycle.

When the antrum and duodenum were well outlined, the rhythmic motor activity described above was recognized with few exceptions at the immediate, the one-hour and the two-hour observations and less often at the end of three and one-half hours. At the five-hour period, the duodenum usually appeared flaccid and dilated, and was traversed by feeble, irregular contractions. Occasionally, moderately deep alternating contractions persisted. No barium was observed passing the site of the obstruction at this time. This may have been because of the fact that the amount propelled beyond the obstruction was too small to be detected fluoroscopically.

The body and fundus of the stomach were often separated from the antrum by a deep contraction band. The antrum maintained a regular rhythm, which seemed to be independent of activity in the cardiac portion of the stomach. In the latter, peristalsis appeared in the form of "ripples," although occasionally, when the waves were sufficiently deep, they were observed traversing the antrum. As a rule, however, they were too shallow for any relationship between them and the antral contractions to be disclosed fluoroscopically.

#### COMMENT

According to Wheelon and Thomas,<sup>14</sup> a rhythmic cycle that follows the "law of the intestine"<sup>16</sup> exists between the antrum, pyloric sphincter and the duodenum. In the normal dog, as soon as the antral peristaltic wave has reached the sphincter, the antrum begins to relax and remains relaxed during the sphincteric and duodenal contractions. The cycle terminates with the reappearance of an antral contraction. Similarly, in chronic duodenal obstruction there was a positive and negative phase of antral activity. Immediately after the wave of contraction passed from the antrum to the sphincter and duodenum, the antrum relaxed and remained inactive during four or five independent secondary contractions in the duodenum. The cycle ended with the reappearance of an antral contraction. However, the duodenum appeared to contract continuously without a phase of relaxation which corresponded to that of the antrum. In the latter, the negative phase seemed to be prolonged and the rate of rhythmic contraction slow.

The accentuated contractions and the reverse motility of the duodenum were due, probably, to changes in tonus associated with the dilatation and to abnormal stimuli arising at the obstruction. The irregular activity of the duodenum represented either exaggerated segmental contractions<sup>14</sup> or independent peristaltic and retroperistaltic waves. The

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16. Bayliss, W. M., and Starling, E. H.: The Movements and Innervation of the Small Intestine, *J. Physiol.* 24:99 (May 11) 1899.

secretion of epinephrine, but Kodama<sup>30</sup> found in his experiments on dogs that ether anesthesia decreases the rate of epinephrine output from the suprarenal glands. Corbett<sup>31</sup> reported a decrease in the epinephrine content of the suprarenal glands in ether anesthesia. In view of these observations, it does not seem plausible to assume that the increased cardiac output during ether anesthesia is associated with changes in the epinephrine content of the blood.

Cullen, Austin, Kornblum and Robinson<sup>32</sup> found an increased oxygen unsaturation of the blood during ether anesthesia. Bloch<sup>32</sup> studied the effect of ether anesthesia on the hemoglobin and red blood cells, and stated that prolonged anesthesia causes degeneration of the red blood cells with the resulting escape of hemoglobin. Harrison and Blalock<sup>33</sup> have found that severe anoxemia causes a marked increase in the cardiac output. The percentage saturation of the arterial blood was decreased in several of the present experiments, and this factor probably plays a part in the increased output of the heart. Since the ether anesthetics were not always associated with a decrease in the percentage saturation, it is thought that all of the change cannot be ascribed to anoxemia.

Part of the increase in the cardiac output during ether anesthesia might possibly be due to the increased respiratory effort during the early stages of the anesthetic. If this change were due entirely to the elevated metabolism of increased work, a parallelism between oxygen consumption and blood flow would be expected. The oxygen consumption usually decreased during ether anesthesia, and the body temperature was lowered by prolonged anesthesia. Yamakita,<sup>34</sup> studying the cerebral blood flow and oxygen consumption in ether anesthesia, found an increase in the stage of excitation, a decrease (over 50 per cent) during the narcosis and an increase after it. In the present report, the increased output of the heart was due to the lessening of the coefficient of utilization (figs. 1 and 2) without any increase in the oxygen consumption.

It is possible that the mechanical effects of changes in the depth of the respiratory movements might cause variations in the venous inflow with a resultant action on the cardiac output. This is improbable, since Marshall<sup>35</sup> has found that the cardiac output of the normal dog is no greater in summer than in winter, although the minute ventilation may be doubled by panting.

30. Kodama, S.: *Tohoku J. Exper. Med.* 4:601, 1924.

31. Corbett, J. F.: *Suprarenal Gland in Anesthesia*, J. A. M. A. 79:543 (Aug. 12) 1922.

32. Bloch, *Deutsche. Ztschr. f. Chir.* 97:132, 1909.

33. Harrison, T. R., and Blalock, A.: Unpublished observations.

34. Yamakita, M.: *Tohoku J. Exper. Med.* 3:414 (Dec.) 1922.

35. Marshall, E. K.: Personal communication, 1925.

## COMMENT

It is interesting to note that, despite active reverse motility in the duodenum, often with an open pylorus, vomiting occurred only twice during the fluoroscopic examinations, and infrequently during the entire period of observation. The symptoms associated with retention and reverse motility in the duodenum have been discussed from a clinical point of view by Wheelon<sup>20</sup> and others. In a series of seventy-four cases reported by Wheelon, only eight presented a history of vomiting. Clinically, chronic duodenal ileus is characterized by many subjective symptoms such as headache, dizziness, nausea, "bilioousness," and a sense of fullness in the epigastrium.

However, since such subjective symptoms cannot be elicited experimentally, it is impossible to draw any analogies. None of the dogs developed the objective nervous symptoms usually associated with intoxication.

In view of the marked alterations in the duodenum associated with chronic obstruction, the possible relationship of such changes to infections of the biliary tract and alterations in the regulation of the flow of bile must be considered. Carlson,<sup>21</sup> Burger<sup>22</sup> and Kodama<sup>23</sup> have emphasized the possible importance of the tonus of the duodenal musculature in the closure of the ampullar end of the common duct. Preliminary studies of the dogs of this series indicate that the gallbladder bile in more than 50 per cent contained large numbers of organisms of intestinal origin.

## CONCLUSIONS

1. A simple method of producing chronic duodenal obstruction in the dog is described.
2. Dilatation and hypertrophy of the duodenum developed above the obstruction.
3. Fluoroscopic examinations confirmed the existence of prolonged duodenal stasis.
4. Alterations in the contractions of the antrum, the pyloric sphincter and the duodenum occurred, and a rhythmic cycle between the three was observed.
5. Except for emaciation in some of the dogs and occasional vomiting, there were no symptoms of intoxication.

20. Wheelon, H.: Symptoms Associated with Duodenal Retention and Reverse Motility, *J. A. M. A.* 86:326 (Jan. 30) 1926.
21. Carlson, A. J.: Physiology of the Liver, *J. A. M. A.* 85:1448 (Nov. 7) 1925.
22. Burger, G. E.: The Regulation of the Flow of Bile, *Am. J. Physiol.* 71: 583 (Nov.) 1925.
23. Kodama, S.: A Model to Simulate the Mechanism of Emptying of the Gallbladder, *Am. J. Physiol.* 77:385 (July) 1926.

The figures obtained for the oxygen capacity of the arterial blood indicate that an anemia was not produced by the anesthetic. Hence, any effect which anemia exerts on the cardiac output can be ruled out in these experiments.

The possible clinical significance of the increase in the cardiac output during ether anesthesia will be considered in subsequent papers.

#### SUMMARY AND CONCLUSIONS

The cardiac output of the heart of the dog during ether anesthesia has been studied by the Fick method. Six experiments were performed on trained animals, and thirteen on dogs to which morphine had been given. The cardiac output of the heart was increased (from 7 to 180 per cent) in all instances except three. These three animals were deeply anesthetized at the time of the determinations. The changes in pulse rate, temperature readings, oxygen consumption, arterial oxygen, venous oxygen, arterial carbon dioxide, venous carbon dioxide, hydrogen ion concentration and cardiac output have been observed. The following statements are true for the dog, and may possibly be true for man.

1. Ether anesthesia causes an increased cardiac output (average increase 76 per cent).

2. The output of the heart is less than normal only when the degree of anesthesia is profound.

3. The increased cardiac output is not associated with an increased oxygen consumption, but is associated with a diminution in the oxygen coefficient of utilization.

4. This change is associated with an increase in the hydrogen ion concentration of the blood, with a decrease in the carbon dioxide content of the blood, and may or may not be accompanied by a diminution in the percentage saturation of the arterial blood.

residues at the end of five hours. It was interesting to note that, in the latter series, six dogs had marked stasis in the duodenum.

The pylorus usually allowed the passage of barium from the stomach to the duodenum at the immediate observation. Sometimes from five to fifteen minutes elapsed before any barium appeared in the duodenum. At the obstruction, after a short delay, barium usually began to enter the distal duodenum and the upper jejunum in varying amounts. However, in two dogs there was a marked delay of one-half hour and two hours, respectively. The latter dog developed symptoms of acute ileus the day after this observation. At the five-hour observation, except for the duodenal and gastric residues noted, the barium was in the large intestine and occasionally in the lower ileum also.

In one dog, the outline of a large oval mass was observed in the greatly dilated duodenum just above the site of the obstruction. It was in the same situation at the three series of observations. However, it did not obstruct the lumen of the duodenum completely, the barium passing around it in a thin film. The mass was probably a large hair ball (a similar one was found in the dilated duodenum of another dog that came to autopsy). This dog is in excellent condition and has evidenced no obstructive symptoms up to the present time.

#### STASIS AND DILATATION

In spite of the fact that the fluoroscopic examinations were started from forty-two to sixty-four days after the last exploratory operation, the notes made at the explorations concerning the degree of dilatation of the duodenum coincided well with the degree of stasis observed roentgenologically. In five dogs, in which a marked dilatation of the duodenum (three or four plus) had been noted, a corresponding five-hour residue existed. In one dog, although only a moderate dilatation (two plus) had been observed, barium was still present in the duodenum at the end of five hours. This was the dog that had the mass in the duodenum described above; the added obstruction probably developed after the last exploratory investigation. In the other dog in which only a moderate dilatation had been observed (two plus), the duodenum was empty at the end of one hour.

Too much emphasis must not be placed on such observations, however, because the degree of stasis varies and is determined by many other factors besides the mere gross dilatation of the duodenum; the degree of the obstruction, the amount of compensatory hypertrophy and tonus of the duodenal musculature, the tonus of the pyloric sphincter, gastric motility, psychic factors, and the character of the food must all be considered. It is unfortunate that earlier fluoroscopic examinations were not made for comparative studies. Koennecke and Meyer<sup>10</sup> noted a five-hour residue in the duodenum of a dog in which the obstruction had existed five weeks.

ment in the ability of the liver to remove the disodium salt of phenol-tetrachlorophthalein from the blood stream, although the liver showed the characteristic atrophic and fatty changes that occur following the establishment of an Eck fistula. Subsequently, Mann and Bollman<sup>5</sup> demonstrated that even large sections of a liver in which an Eck fistula had been established were resected, the elimination of the dye remained within relatively normal limits.

The present series of experiments includes a study of the effects of prolonged stasis in the duodenum, a part of the intestinal tract that is characterized normally by its rapid motility and relative freedom from bacteria. The first two papers of this series deal with the technic, physiology and bacteriology of experimental chronic duodenal obstruction.

During the last few years, numerous clinical observations have been made concerning the relationship between duodenal stasis and systemic disease. A clinical syndrome due to chronic duodenal ileus has been described, and relief of symptoms has been obtained by releasing the mechanical obstruction.<sup>6</sup> A marked increase in the bacterial content of the duodenum has been noted in cases of pernicious anemia, inflammatory diseases of the biliary tract and various gastric disturbances.<sup>7</sup> Chronic intestinal obstruction has been found to coexist with some cases of pernicious anemia. An important rôle in the genesis of this disease has been ascribed to the absorption of hematoxins from the intestine associated with a marked increase in the number of bacteria of the small intestine.<sup>8</sup> Brown and his co-workers<sup>9</sup> have described a toxic nephritis associated with "duodenal toxemia."

Nothing has appeared in the literature concerning the experimental production of chronic duodenal obstruction, except the work of Koennecke and Meyer.<sup>10</sup> These authors believed that chronic duodenal

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5. Mann, F. C., and Bollman, J. L.: An Experimental Study of Reduced Hepatic Function, *Am. J. Physiol.* **76**:179 (March) 1926; Liver Function Tests, *Arch. Path. & Lab. Med.* **1**:681 (May) 1926.

6. Higgins, C. C.: Chronic Duodenal Ileus with Report of Fifty-Six Cases, *Arch. Surg.* **13**:1 (July) 1926.

7. Olivet, J.: Bakteriologie des Duodenum, *Klin. Wchnschr.* **5**:307 (Feb. 19) 1926. Löwenberg, W.: Pathologische Bakterienansiedlung im Duodenum und ihre Ursächlichen Faktoren, *Klin. Wchnschr.* **5**:548 (March 26) 1926.

8. Seyderhelm, R.: Die Bedeutung des Dünndarms für die Genese der Perniziösen Anämie, *Klin. Wchnschr.* **3**:568 (April 1) 1924. Seyderhelm, R.; Lehmen, W., and Wichels, P.: Experimentelle Intestinale Perniziöse Anämie beim Hund, *Klin. Wchnschr.* **3**:1439 (Aug. 5) 1924.

9. Brown, G. E.; Eusterman, G. B.; Hartman, H. R., and Rowntree, L. G.: Toxic Nephritis in Pyloric and Duodenal Obstruction, *Arch. Int. Med.* **32**:425 (Sept.) 1923.

10. Koennecke, W., and Meyer, H.: Klinisches und Experimentelles zur Chronischen Duodenalstenose, *Deutsche Ztschr. f. Chir.* **175**:179 (Sept.) 1922.



# EXPERIMENTAL CHRONIC DUODENAL OBSTRUCTION

## II. BACTERIOLOGY \*

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In the search for a possible origin of some of the chronic and sub-acute illnesses of men in which there seems to be clinical evidence of a low grade intoxication, attention has recently been focused on the gastro-intestinal tract. In a previous paper, two of us with Cone<sup>1</sup> reported the failure to obtain evidence of absorption of toxic substances from the normal intestine in dogs that had Eck fistulas and that were kept on a meat diet. We were then led to study the effect after a partial obstruction of the intestine. It became evident at once that it would be necessary, before going further, to study the altered anatomy and physiology as well as the changes in the bacterial content of the intestine resulting from this procedure. In the paper immediately preceding this,<sup>2</sup> we have endeavored to indicate certain of the anatomic and physiologic alterations. In the present paper we shall present our observations with regard to the bacteriologic changes.

## HISTORICAL

Ever since Billroth<sup>3</sup> made the observation that the meconium of new-born babes was free from bacteria, and that micro-organisms made their appearance in the first yellow stools, bacteriologists and clinicians have been interested in the bacterial content of the intestine. Their interest has led to extensive researches to determine, if possible, the significance of the countless organisms which grow in the alimentary canal of animals and man. Their behavior during the normal physiologic

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\* This work was aided by a grant from the Eli Lilly Company.

1. Berg, B. N.; Cone, W. V., and Jobling, J. W.: Phenoltetrachlorphthalein Test of Liver Function in Eck Fistula Dogs Kept upon a Meat Diet, *Proc. Soc. Exper. Biol. and Med.* **23**:81, 1925.

2. Berg, B. N.; Meleney, F. L., and Jobling, J. W.: Experimental Chronic Duodenal Obstruction. I. Technic and Physiology, *Arch. Surg.*

3. Billroth, T.: Untersuchungen über Vegetationsformen von Coccobacteria Septica, Ser. 94, Berlin, 1874. (Quoted by Cushing and Livingood: *Johns Hopkins Hosp. Rep.* **9**:543, 1900).

The effects of the partial obstruction on the segment of the duodenum proximal to it as shown in the accompanying table, varied in the different animals. At exploratory operation, in seven dogs a three or four plus dilatation was found from sixty-three to one hundred and twenty-one days after the establishment of the obstruction; in five dogs, a two plus dilatation was present in from thirty-five to one hundred and nineteen days.

Some of the dogs vomited during the first twenty-four hours after the operation. For the first few days, they ate little food. Subsequently, none of them exhibited any objective symptoms except occasional vomiting. Seven dogs lived for periods varying from fifty-nine to 190 days after the obstruction was established. Shortly before death, five developed symptoms of acute ileus; two were killed. Of the seven dogs in this series, four became emaciated. The remaining five are alive, and had been under observation for from 174 to 240 days on September 15.

*Degrees of Dilatation After Obstruction\**

Number of Dog	First Exploratory Operation; Days after Obstruction	Degree of Dilatation	Second Exploratory Operation; Days after Obstruction	Degree of Dilatation	Third Exploratory Operation; Days after Obstruction	Degree of Dilatation	Autopsy; Days after Obstruction
8100	17	+	81 T	++	119	++++	109
8191	17	++++	77	++++	121	++++	...
8209	10	+	70 T	++	119	++	...
8295	39	++	103	++	...	..	113
8313	35 T	++	..	..	...	..	73
8314	35	+++	60	+++	...	..	...
8332	49 T	++	70	+++	...	..	...
8360	49 T	++	..	..	...	..	79
8361	45 T	++	80	+++	...	..	151
8364	45	++	79	+++	...	..	161
8417	39	++++	63	++++	...	..	84
8418	32 T	+	66	++	...	..	...

\* In the table, + represents slight dilatation; ++, moderate dilatation (less than twice the normal diameter); +++, marked dilatation (about twice the normal diameter), and +++++, extreme dilatation (more than twice the normal diameter); T, fecal band tightened at this operation.

The nutrition of these dogs remains unimpaired. No abnormalities of the stools were observed. Complete autopsy observations will be included in a later report.

#### PHYSIOLOGY

The fluoroscopic observations in clinical cases of duodenal obstruction have been described by Jordan,<sup>11</sup> Wheelon,<sup>12</sup> Koenecke and Meyer,<sup>10</sup> Ratkoćzi<sup>13</sup> and others. In general, they found stasis and reverse motility in the duodenum, gastric and duodenal hyperperistalsis.

11. Jordan, A. C.: The Duodenum and the Appendix in Intestinal Stasis. Brit. M. J. 1:1225 (June 1) 1912.

12. Wheelon, H.: Observations on Gastric and Duodenal Motility in Duodenal Obstruction, J. A. M. A. 77:1404 (Oct. 29) 1921.

13. Ratkoćzi, N.: Chronic Stenosis of Duodenum, Am. J. Roentgenol. 12: 246 (Sept.) 1924.

on the stomach and duodenum and presented cases to prove that the suggestion was a worthy one.

Since the publication of these observations, a number of authors have reported work which confirms many of the observations of Cushing and Livingood. The duodenal bucket has afforded to many observers, Libert,<sup>5</sup> Hoefert<sup>6</sup> and others, the opportunity to study the bacteria of the duodenum under normal and disease conditions. There is general uniformity of opinion that bacteria are found in the upper intestine in relatively small numbers under normal conditions of the stomach and biliary tract, but that the organisms in the mouth and pharynx and those contaminating the food and drink are found in great numbers if the gastric acidity is low, or if the biliary tract is diseased. In 1918 and 1919, Kendall,<sup>7</sup> and Torrey,<sup>8</sup> and others since that time, found that changes in diet modify the flora of the intestine, certain types of bacteria being favored by certain food elements and inhibited by others. Rettger and Cheplin<sup>9</sup> asserted that certain bacteria may be introduced into the intestine and maintain an existence for a time, retarding the development of other bacteria which are considered harmful. Dragstedt and his co-workers<sup>10</sup> confirmed the observation that diet modifies the flora of the intestine, but stated that if intestinal stasis or acute intestinal obstruction is produced, no matter what the predominating types were before, the putrefactive bacteria promptly become predominant and may be responsible for the intoxication found in those conditions.

One is surprised to find that many of the reports in the literature do not mention that anaerobic cultures have been made; others state that there was no difference between the aerobic and anaerobic cultures. Many authors noted that bacteria frequently were seen in smears which could not be cultivated. Cushing and Livingood,<sup>4</sup> particularly, described a large bacillus which was often present but which would not grow. It is possible that these were anaerobes which could not develop in the degree of anaerobiosis attained by these workers. Others have appreciated the importance of anaerobic cultures.

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5. Libert, Edmond: *Le tubage duodenal; Ses applications au diagnostic et au traitement. Considerations sur la flore duodénale normale et pathologique*, Paris, 1924.

6. Hoefert, Bruno: *Ueber Bacterienbefunde im Duodenalsaft von Gesunden und Kranken*, *Ztschr. f. klin. Med.* **92**:221-225 (Nov.) 1921.

7. Kendall, A. I.: *Recent Developments in Intestinal Bacteriology*, *Am. J. M. Sc.* **156**:157-172 (Aug.) 1918.

8. Torrey, J. C.: *The Regulation of the Intestinal Flora of Dogs through Diet*, *J. M. Research* **39**:415-447 (Jan.) 1919.

9. Rettger, L. F., and Cheplin, H. A.: *A Treatise on the Transformation of the Intestinal Flora*, New Haven, Yale University Press, 1921.

10. Dragstedt, L. R.; Cannon, P. R., and Dragstedt, C. A.: *Factors Controlling the Intestinal Bacteria. The Effect of Acute Obstruction and Stasis on Bacterial Types*, *J. Infec. Dis.* **31**:209-214 (Sept.) 1922.

size; in others, the dilatation was less pronounced. Variations also occurred in the same dog at different observations. These changes were probably the result of alterations in tonus; because of this it was considered futile to compare roentgenographic appearances with gross dilatation observed at exploration. However, there seemed to be some correlation between the latter and the degree of stasis. This is discussed in detail under the heading of stasis and dilatation.

After the filling of the duodenum, the following cycle was observed in six of the seven dogs that were examined: A deep peristaltic contraction appeared in the antrum and progressed toward the pylorus; sometimes the entire antrum appeared to contract at one time instead of in the form of a peristaltic wave. As the wave approached the pylorus, the latter opened and barium passed through into the duodenum; then the pylorus closed, and the contraction traversed the duodenum, causing a marked bulge in the latter as it approached the obstruction. Immediately after this there appeared a definite to-and-fro motion of the mass of barium in the duodenum (apparently independent of the antrum), the result of deep contractions that traveled alternately toward the obstruction and then toward the pylorus. During reverse movements, the bulb was momentarily distended, especially when the sphincter was closed. At some observations, the sphincter was open, and reflux into the antrum occurred. After four or five of these alternating contractions, peristaltic activity in the antrum appeared anew, and the rhythmic cycle was repeated. In the interval between contractions, the antrum appeared to be inactive and usually only partly filled with barium. Sometimes it was empty, possibly because of a tonic contraction of the so-called "sphincter antri pylorici"<sup>15</sup> or of the antrum itself. Similarly, the duodenum at times did not contain barium; this may have been caused by a tonic contraction of either the pyloric sphincter or of the duodenum. In such cases, the cycle could not be distinguished. In one dog, in which there was apparently slight obstruction, the cycle was not observed. It will be noticed throughout the remainder of the study that this dog was practically normal.

Sometimes, when the lower or middle portion of the duodenum was tonically contracted, the cycle could be identified only in the upper duodenum and bulb. When reflux into the antrum was marked, the duodenum and antrum appeared to be continuous, and it was more difficult to distinguish the cycle. It seemed as though the antral peristaltic wave spent itself more rapidly than usual, because of increased resistance from irregular contractions in the duodenum. At many observations, the barium was propelled beyond the obstruction in jets, which followed only duodenal contractions of antral origin. At other times,

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15. Hofmeister, F., and Schütz, E.: *Über die Automatischen Bewegungen des Magens*, Arch. f. Exper. Path. u. Pharmacol. 20:1 (Oct. 6) 1886.

gray colonies of gram-negative bacilli and small green colonies of cocci. The anaerobic plates from the second and third tubes developed typical *B. welchii* colonies, and small gray colonies of gram-negative bacilli. The aerobic plates from these tubes showed only large gray colonies of gram-negative bacilli. The anaerobic plates from the fourth and fifth tubes again showed *B. welchii* colonies, while the aerobic plates did not show any growth. From such observations one could estimate that there were between 10 and 100 aerobic gram-positive cocci, between 1,000 and 10,000 aerobic gram-negative bacilli and between 100,000 and 1,000,000 anaerobic gram-positive bacilli in one cubic centimeter of the original fluid.

#### EXPERIMENTAL RESULTS

In a preliminary series, the obstruction was made just above the ileocecal valve. In eleven dogs, specimens of fluid were taken from the duodenum, lower jejunum and lower ileum just above the occlusion. The results in this series were unsatisfactory, since all but one dog died as a result of the procedure. The causes of death included general peritonitis, acute obstruction and pneumonia. However, certain of the preliminary results are of interest and are included here, particularly the ante-obstruction observations of bacteria in the duodenum. The results from these eleven normal dogs were added to the figures from the fourteen dogs of a later series in which the obstruction was placed at the lower end of the duodenum. Thus we obtained cultures from the duodenum of twenty-five normal animals.

In the early experiments the organisms found in the lower intestine belonged to many types which could not be classified, and a complete analysis was not practical. However, the bacteria in the duodenal fluid were few in number and variety and in almost all cases could be isolated and identified. It soon became evident that there were three principal bacterial groups, namely, aerobic gram-negative bacilli of the *B. coli* group, aerobic gram-positive cocci of the nonhemolytic or green streptococcus group and anaerobic gram-positive bacilli of the *B. welchii* group. Other organisms rarely found were *B. proteus*, *Staphylococcus aureus* and *albus*, *B. sporogenes* and certain gram-positive aerobic bacilli. In the later experiments, no attempt was made to classify the organisms further than to put them into one of these three groups. The results are given in table 1.

A survey of these results brings out certain points of more or less significance. First, let us take the normal series. In only one of the twenty-five (4 per cent) was the duodenum sterile. In seven, the Welch bacilli existed alone. In three, the streptococci and in one the colon bacilli existed alone. In six, all three forms were found. The cocci were present in fourteen and absent in eleven. The gram-negative bacilli were present in eleven and absent in fourteen. The gram-positive anaerobic bacilli were present in seventeen and absent in eight. It is seen that the gram-positive anaerobic bacillus was the type most con-

delayed motility, especially at the five-hour observation, may be explained by alterations in the "gradient," as described by Alvarez.<sup>17</sup>

The tonicity of the pyloric sphincter varied during the phase of independent duodenal activity. At some observations, it appeared contracted; at others, it allowed reflux into the antrum. The activity of the sphincter can be modified by duodenal motility during the negative phase of the antrum.<sup>14</sup> The prolonged reverse motility of the obstructed duodenum probably induced marked alterations in the pyloric sphincter, which, however, were not recognized by the fluoroscope.

The site of origin of the antral peristaltic contraction, which appeared to be independent of activity in the fundus and body of the stomach, requires finer methods of study for a more accurate interpretation. Recently, Klein<sup>18</sup> found that, normally, antral contractions may originate either at a nodal center near the cardia, along the lesser curvature of the stomach, or independently, at a separate nodal center at the reentrant angle.

#### STASIS

In all of the dogs, there was a delay in the passage of the barium through the duodenum proximal to the site of the obstruction. The emptying time and the amount of residue varied. In four dogs, there was a persistent residue at the end of five hours; in two dogs, the duodenum was filled with barium at one five-hour observation, but was empty at another. In one dog, the duodenum was always empty at the one-hour observation. This dog was referred to earlier as having practically no delay in motility.

More pronounced variations occurred in the emptying time of the stomach. However, marked irregularities also exist normally. At one observation of a normal, fasting dog, the stomach was empty at the end of one hour; at another observation of the same dog, a gastric residue was still present at the end of three hours. Wheelon and Thomas<sup>19</sup> noted similar variations in the dog and in man. Bloomfield and Keefer,<sup>19</sup> employing a different method, recently reported wide differences in the motility of the normal stomach in man.

In chronic duodenal obstruction, the stomach always contained barium at the one-hour observation, except in the dog in which the obstruction apparently had little effect. In one series, four dogs had five-hour gastric residues. In another series none of the dogs had

17. Alvarez, W. C.: *The Mechanics of the Digestive Tract*. New York, Paul B. Hoeber, Inc., 1922.

18. Klein, E.: Gastric Motility: Origin and Character of Gastric Peristalsis, *Arch. Surg.* **12**:571 (Feb.) 1926.

19. Bloomfield, A. L., and Keefer, C. S.: Clinical Physiology of the Stomach: Simultaneous Quantitative Observations on Gastric Secretory Volume, Activity and Motility, *Arch. Int. Med.* **38**:145 (Aug.) 1926.

present in ten and absent in two. The gram-positive anaerobic bacilli were present in eleven and absent in one. It is seen that there was a striking increase in all types. In general, the greatest increase in numbers was found when the greatest dilatation was present, but this was not invariable. Fluoroscopic examinations as reported in the previous paper revealed the fact that the delay in emptying almost always corresponded closely to the degree of dilatation.

It is seen that certain types were present after obstruction which were not found before, and vice versa; also that the type predominating before had no certainty of predominating afterward. In general, the gram-negative bacilli increased more than the others but not strikingly, as Dragstedt<sup>10</sup> reported for his cases of acute obstruction.

When little obstruction was present, it was increased slightly at the time of the second operation by tightening the band. When eleven of the animals were examined a third time, from fifty-nine to 108 days after obstruction, it was found again that in no case was the duodenum sterile, and in no instance did a single type exist alone. In ten, all three types were present. The cocci were present in ten and absent in one. The gram-negative bacilli and the gram-positive anaerobic bacilli were present in all instances. It is seen also that there was a general increase in the number of all three types. Again, it is seen that the predominating type changed, and that the gram-negative bacilli gained more than the others. In every instance but one, the degree of dilatation either had been maintained or had increased.

Three animals were examined a fourth time, from 119 to 121 days after obstruction, and again the gut was not sterile in any instance. In all of the cases all three types were present, but the numbers were less than at the time of the preceding examination. The gram-negative bacilli, however, maintained their numbers better than either of the others. The degree of dilatation was somewhat increased.

In eleven of the twelve dogs having a third or fourth examination, cultures were made not only of the fluid in the gut above the obstruction but also of that from the lower jejunum for comparison. The gut immediately below the obstruction frequently was found collapsed, and in the region of the middle of the gut this condition was also often present. In seven of these cases the number of organisms in the lower jejunum was less than in the duodenum above the obstruction. In three of these seven, certain types which were present above the obstruction were absent below. These results are shown in table 2.

At the same time, cultures were made of bile taken from the gall-bladder by aspiration without primary dilution. In six of the eleven cases, organisms were found in considerable numbers. These observations are of great interest and warrant a more extensive study.

residues at the end of five hours. It was interesting to note that, in the latter series, six dogs had marked stasis in the duodenum.

The pylorus usually allowed the passage of barium from the stomach to the duodenum at the immediate observation. Sometimes from five to fifteen minutes elapsed before any barium appeared in the duodenum. At the obstruction, after a short delay, barium usually began to enter the distal duodenum and the upper jejunum in varying amounts. However, in two dogs there was a marked delay of one-half hour and two hours, respectively. The latter dog developed symptoms of acute ileus the day after this observation. At the five-hour observation, except for the duodenal and gastric residues noted, the barium was in the large intestine and occasionally in the lower ileum also.

In one dog, the outline of a large oval mass was observed in the greatly dilated duodenum just above the site of the obstruction. It was in the same situation at the three series of observations. However, it did not obstruct the lumen of the duodenum completely, the barium passing around it in a thin film. The mass was probably a large hair ball (a similar one was found in the dilated duodenum of another dog that came to autopsy). This dog is in excellent condition and has evidenced no obstructive symptoms up to the present time.

#### STASIS AND DILATATION

In spite of the fact that the fluoroscopic examinations were started from forty-two to sixty-four days after the last exploratory operation, the notes made at the explorations concerning the degree of dilatation of the duodenum coincided well with the degree of stasis observed roentgenologically. In five dogs, in which a marked dilatation of the duodenum (three or four plus) had been noted, a corresponding five-hour residue existed. In one dog, although only a moderate dilatation (two plus) had been observed, barium was still present in the duodenum at the end of five hours. This was the dog that had the mass in the duodenum described above; the added obstruction probably developed after the last exploratory investigation. In the other dog in which only a moderate dilatation had been observed (two plus), the duodenum was empty at the end of one hour.

Too much emphasis must not be placed on such observations, however, because the degree of stasis varies and is determined by many other factors besides the mere gross dilatation of the duodenum; the degree of the obstruction, the amount of compensatory hypertrophy and tonus of the duodenal musculature, the tonus of the pyloric sphincter, gastric motility, psychic factors, and the character of the food must all be considered. It is unfortunate that earlier fluoroscopic examinations were not made for comparative studies. Koennecke and Meyer<sup>10</sup> noted a five-hour residue in the duodenum of a dog in which the obstruction had existed five weeks.



and antagonism of bacteria are questions which have been studied greatly but have not been elucidated. Castellani<sup>12</sup> has recently made some simple and convincing experiments which indicate definitely that certain organisms when growing together may perform certain functions which neither could accomplish alone.

The fact that down in the middle of the intestine the viable bacteria were frequently less than above the obstruction suggests that, with the passage of the food mass and a collapse of the tube, there may be some antiseptic action by the gut mucosa on the bacteria in immediate contact with it. It is probable that many bacteria penetrating the wall are destroyed. Radel,<sup>13</sup> tried but failed to demonstrate any growth-inhibiting substance in extracts or emulsions of the stomach or intestinal wall, and suggested that whatever the antiseptic action, it must be a function of living cells. This may be something of the same nature as that which prevents digestion of the living mucosa by the digestive fluids.

Our observations with regard to the presence of bacteria in the bile of certain of the dogs with duodenal obstruction is of considerable importance and will be continued and carefully controlled. A report will be made in a subsequent paper.

It has been found repeatedly by many observers that the lower gut is in contact with billions of organisms, while the duodenum normally is not. The question arises whether the lower gut normally has any resistance to the action or invasion of these organisms which the duodenum has not. May such resistance be developed by the duodenum after prolonged contact with them? Although the cases are too few to draw conclusions, there is a suggestion, in the falling off in numbers of bacteria in the examinations made in the later stages of obstruction, that this feature of the problem may well merit investigation. One is reminded of the intestinal immunity results of Besredka in this connection.<sup>14</sup>

#### SUMMARY

1. In the duodenum of our dogs, bacteria were normally present. In 70 per cent of cases anaerobic gram-positive bacilli of the *B. welchii* type were found. In 50 per cent, varieties of the nonhemolytic strepto-

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12. Castellani, A.: The Importance of Symbiosis or Close Association of Different Species of Organism in the Production of Certain Biochemical Phenomena and in the Causation of Certain Diseases and Certain Symptoms of Diseases, *J. A. M. A.* 87:15-22 (July 3) 1926.

13. Radel, F. W.: Sind in der Dünndarmschleimhaut Bakterienwachstum Hemmende Stoffe (Bakteriostanine) nachweisbar? *Ztschr. f. d. ges. exper. Med.* 48:658-670, 1926.

14. Besredka, A.: *Immunisation Locale Pansements Spécifiques*, Paris, Masson & Cie., 1925.

## COMMENT

It is interesting to note that, despite active reverse motility in the duodenum, often with an open pylorus, vomiting occurred only twice during the fluoroscopic examinations, and infrequently during the entire period of observation. The symptoms associated with retention and reverse motility in the duodenum have been discussed from a clinical point of view by Wheelon<sup>20</sup> and others. In a series of seventy-four cases reported by Wheelon, only eight presented a history of vomiting. Clinically, chronic duodenal ileus is characterized by many subjective symptoms such as headache, dizziness, nausea, "biliousness," and a sense of fulness in the epigastrium.

However, since such subjective symptoms cannot be elicited experimentally, it is impossible to draw any analogies. None of the dogs developed the objective nervous symptoms usually associated with intoxication.

In view of the marked alterations in the duodenum associated with chronic obstruction, the possible relationship of such changes to infections of the biliary tract and alterations in the regulation of the flow of bile must be considered. Carlson,<sup>21</sup> Burget,<sup>22</sup> and Kodama<sup>23</sup> have emphasized the possible importance of the tonus of the duodenal musculature in the closure of the ampullar end of the common duct. Preliminary studies of the dogs of this series indicate that the gallbladder bile in more than 50 per cent contained large numbers of organisms of intestinal origin.

## CONCLUSIONS

1. A simple method of producing chronic duodenal obstruction in the dog is described.
2. Dilatation and hypertrophy of the duodenum developed above the obstruction.
3. Fluoroscopic examinations confirmed the existence of prolonged duodenal stasis.
4. Alterations in the contractions of the antrum, the pyloric sphincter and the duodenum occurred, and a rhythmic cycle between the three was observed.
5. Except for emaciation in some of the dogs and occasional vomiting, there were no symptoms of intoxication.

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20. Wheelon, H.: Symptoms Associated with Duodenal Retention and Reverse Motility, *J. A. M. A.* **86**:326 (Jan. 30) 1926.

21. Carlson, A. J.: Physiology of the Liver, *J. A. M. A.* **85**:1468 (Nov. 7) 1925.

22. Burget, G. E.: The Regulation of the Flow of Bile, *Am. J. Physiol.* **74**: 583 (Nov.) 1925.

23. Kodama, S.: A Model to Simulate the Mechanism of Emptying of the Gallbladder, *Am. J. Physiol.* **77**:385 (July) 1926.

# A REVIEW OF UROLOGIC SURGERY

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## KIDNEY

*Surgical Technic.*—Bugbee<sup>1</sup> cites cases to illustrate problems of renal surgery. These case reports and the discussion of them emphasize the following points:

Hematuria, however slight, may be of extreme importance and should never be passed over without thorough and repeated study. By such means renal tumors will be diagnosed much more often, and in their incipency, when cure may be possible.

There are many and varied types of renal tuberculosis, the more chronic forms being probably often misunderstood. Nature develops remarkable resistance to this type of infection. Such resistance should be utilized to the fullest in the treatment of these cases.

Anomalous renal vessels as a cause of ureteral obstruction and resulting hydronephrosis are more common than has been believed previously. Pyelography in these cases may give a fairly definite picture. Temporizing is of no avail.

Renal calculi call for a most careful study of each case, the best judgment in outlining the proper procedure to be followed and careful operative technic.

Conservatism in deciding on operation, the proper preparation of the patient for operation, conservation of renal tissue, nephrotomy preliminary to nephrectomy in the presence of serious surgical risk, the free employment of transfusion and intelligent after-care will go far toward placing renal surgery in its proper place as one of the most interesting, accurate and satisfactory branches of surgery.

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1. Bugbee, H. G.: Some Interesting Problems in Renal Surgery, *J. Urol.* 15:431-448 (May) 1926.

function of the digestive tract is doubtless the outcome of age-long mutual adaptation which has resulted in the establishment of a relative equilibrium. The host survives with comparatively little evidence of injury to itself, and the bacteria maintain their species with relatively unimportant variation in numbers. Studies of this so-called normal relationship are interesting, but the disease phenomena which result from the invasion of the body by these bacteria after injuries to or the absorption of their products following altered physiologic processes of the alimentary canal makes fascinating problems for research.

Surgeons observed long ago that wounds of the stomach and upper intestine were not always followed by peritonitis as were wounds of the lower intestine. They found that operations in the upper regions could be performed with impunity, while sections of the lower portions were attended with grave risk of death. On the other hand, occlusions of the intestine produced profound symptoms of intoxication which were greater and more rapidly fatal when they were in the upper levels than when they were lower down. Cushing and Livingood,<sup>4</sup> were stimulated by the former observations to attempt a study of the bacteria from the human stomach, duodenum and jejunum, taking specimens as opportunity afforded at the time of or after operations on the alimentary canal and from fecal fistulas, for the most part in pathologic conditions. They also studied the intestinal fluid at various levels in rabbits and dogs. Old as it is, their work has many points of interest in the present discussion, and reference to it merits some detail. They were struck by the irregularity of their results, and concluded that there were no peculiar or stable flora in the intestine except perhaps *Bacillus coli* in the lower intestine. They found "no marked differences between the colonies on aerobic and anaerobic plates" but frequently saw bacteria in smears, which they could not cultivate. They confirmed the observations of previous research workers that there were many more bacteria in the lower than in the upper intestine. They noted, however, that the number at all levels decreased greatly after starvation, and that the lower limb of a fecal fistula became sterile. They concluded that bacteria were ingested with food and water and were killed in large numbers in the stomach if the food were delayed there for a time. Viable bacteria were therefore scanty in the duodenum but multiplied rapidly during their passage through the small intestine. After the passage of the chyme, if no more food was taken, the intestine tended to become amicrobic. They recommended the abstinence from food preliminary to operations

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4. Cushing, H., and Livingood, L. E.: Experimental and Surgical Notes upon the Bacteriology of the Upper Portion of the Alimentary Canal, with Observations on the Establishment There of an Amicrobic State as a Preliminary to Operative Procedures on the Stomach and Small Intestine, *Johns Hopkins Hospital Rep.* 9:543, 1900.

segmentary, involving only part of the excretory tract. The ureteral orifices may take part in the process. The congenital nature of the lesion is suggested by the extent of the dilatation, the early age at which it usually occurs, the absence of mechanical obstructions or of cerebro-spinal lesion, the occasional bilateral incidence of the condition and the association of other well recognized congenital malformations, such as polycystic kidneys, coccygeal anomalies, spina bifida and hypospadias. The author advocates the pathogenic hypothesis that the anomaly affecting the urinary apparatus of the kidney results from a dystrophic condition similar to that causing polycystic kidneys. This dystrophic condition is of the same group as that which brings about megalavesica and megacolon. The congenital lesions seem to affect primarily the nerve fibers, which brings about atony and, later, dilatation of the pelvis and ureters. The slight hypertrophy of the muscular coat, found on histologic examination, explains the fight of these ducts against the dynamic troubles with which they are confronted. Cases of segmentary dilatation are due to limited involvement of the urinary sympathetic plexus. On the other hand, some cases probably result from the persistence of the relative dilatation of the ureter and kidney existing in the fetus till the fifth month. The symptoms are not clear. Many cases, particularly those of the segmentary type, remain latent. Chronic incomplete retention is often the accident which reveals the others. In most cases there is a remarkable adaptation of the organism, with the maintenance of renal secretory activity sufficient to support life, in spite of the extent of the lesion. The diagnosis is impossible without a complete urologic examination. A simple cystoscopic observation is sufficient to make the diagnosis in cases in which the dilatation extends to the ureteral orifices. Ureteral catheterization may sometimes be a guide in showing pelvic retention or in exhibiting a vesicorenal "reflux." Valuable diagnostic help is derived from pyelography and cystopyelography.

Walther <sup>4</sup> reports a case of bilateral double renal pelvis and ureter in a woman, aged 65. Cystoscopy, because of pyuria and pain under the right shoulder blade and in both flanks, showed double ureteral orifices on the right and left; a pyelogram made of each side showed complete duplication of pelvis and ureter on each side. There was infection of the lower part of the pelvis on the left. The patient died and the condition was demonstrated at necropsy.

In commenting on complete bilateral duplication of the pelvis and ureter, Walther states that this case brings the total number reported up to fifty-one. The condition represents from 6 to 27 per cent of the anomalies of the upper part of the urinary tract, according to various investigators. The importance of always looking for a second ureteral

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4. Walther, H. W. E.: Bilateral Duplication of Renal Pelves and Ureters, *Ann. Surg.* 82:968-970 (Dec.) 1925.

With the idea that the anaerobic organisms might be significant in certain types of intestinal obstruction, we have made both aerobic and anaerobic cultures in the present study. We have also attempted to correlate our observations with the anatomic and certain of the physiologic conditions revealed at subsequent operations.

#### TECHNIC

In a previous paper, we have described the technic of partial duodenal obstruction in dogs.<sup>2</sup> The principle is to use a living sheet or band of parietal peritoneum and posterior sheath of the rectus from the abdominal wall and to diminish the lumen of the gut to considerable degree without obstructing it completely. All food was withheld from the animals for thirty-six hours before operation, and water was withheld for sixteen hours. Specimens of duodenal fluid were obtained by stripping the gut approximately 10 cm. from the pylorus and clamping 5 cm. of the duodenum thus stripped between two rubber protected clamps. We estimated that this left approximately 0.5 milliliter of fluid, held largely between the crypts and folds of the gut. With a syringe and a no. 16 Luer needle, this segment of the gut was washed thoroughly with 5 milliliters of the supernatant fluid from 0.2 per cent dextrose cooked meat medium from which the air had been driven by boiling. The needle hole was closed with a purse string suture previously laid and tied as the needle was withdrawn. One milliliter of this fluid was then planted into a tube of dextrose cooked meat medium, and 0.1 milliliter was transferred to the first of a series of twelve tubes, each containing 0.9 milliliter of the supernatant broth. After thorough shaking, 0.1 milliliter was transferred from the first to the second tube and so on through the series. Thus each tube contained approximately one tenth of the bacteria present in the preceding tube. Allowing for experimental error, the number of organisms present could be estimated within one digit. The fluid withdrawn after washing the segment of the gut represented an approximate dilution of from 1-10. In the small tubes, the dilutions ranged from one to one hundred to one to ten trillion. The tubes were then incubated under strict anaerobic conditions in a McIntosh and Fildes jar.<sup>11</sup> In this medium under these conditions, both aerobes and anaerobes develop satisfactorily. After twenty-four hours culture, streaks were made on 5 per cent sheep blood agar plates from the tubes showing growth. One set of plates was incubated aerobically and another set anaerobically. Smears from the broth indicated to what dilution each type of organism had been distributed. On the next day, the plates were examined to confirm the observations in the tubes. Individual colonies could then be fished for further identification. From these tubes and plates, an estimate could be made of the number of viable organisms of each type in the original duodenal fluid. For example, let us say that five of the small tubes showed growth. In the first tube, gram-positive cocci, large gram-positive bacilli and small gram-negative bacilli were found. Gram-positive and gram-negative bacilli were present in the second and third tubes, but only gram-positive bacilli in the fourth and fifth. The anaerobic plates made from the first of these tubes showed the typical large double zoned colonies of *B. welchii*, small gray colonies containing gram-negative bacilli and small colonies of cocci which turned green on exposure to the air. The aerobic plate from the first tube showed only large

11. McIntosh, J., and Fildes, P.: A New Apparatus for the Isolation and Cultivation of Anaerobic Microorganisms, *Lancet*, 1:768-770 (April 9, 1917).

localized perirenal adhesions, and thus difficult to identify. The original pelvic duplication of the kidney has doubtless occasionally been overlooked.]

Eisendrath, Phifer and Culver<sup>5</sup> review the cases of horseshoe kidney reported in the literature and add three of their own. This anomaly occurs about once in from 715 to 862 necropsies. The halves may be symmetrical or asymmetrical. As a rule they lie at an equal distance from the spine, but one or both halves may be displaced, one half lying close to the spine and the other half far away. As a rule, the lower poles converge. The isthmus joins the lower poles in about 90 per cent of the cases, the upper poles in about 10 per cent. In seven of the cases studied, the isthmus was fibrous, but in the majority it was composed of parenchyma without any line of division between the halves. The transition to the so-called cake kidney is mentioned as being present in many cases so that there may be an area of demarcation between the two kidneys. In two cases only was the isthmus found behind the aorta.

In most cases there was a complete pelvis in each half, yet duplication of the pelvis or double pelvis in one side or both was encountered at times. In horseshoe kidney the calices are at times extrarenal and end independently in the ureter. As a rule the ureters pass across the isthmus. Sometimes the isthmus itself may have an independent ureter. Usually calices are present only in the upper half or two-thirds, but an extrarenal calix may drain the isthmus and may be opened during the operation of heminephrectomy.

The site of the horseshoe kidney may be anywhere from the normal level to the true pelvis, although it usually is below the aortic bifurcation. The fixation is in a measure due to the fact that it has multiple blood vessels supplying it, all from immediately adjacent trunks. Multiple vessels for each half and often for the isthmus as well are found in 80 per cent of the cases. The importance of this in operative considerations is obvious.

The course of the ureter across the isthmus, the abnormal site of the pelvis on the ventral aspect of the kidney, the frequent insertion of the ureter at a point higher than the bottom of the pelvis and the frequent absence of a pelvis are productive of pathologic conditions. Congenital stricture of the ureter is common in cases of horseshoe kidneys, and the presence of many anomalous vessels adds to the possibility of ureteral obstruction.

There are no symptoms pathognomonic of the anomaly. Abdominal pains are presumably due to the pressure of the isthmus. The most characteristic feature of these pains is their increase when the patient leans forward or exerts himself, and their complete disappearance when the patient lies down.

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5. Eisendrath, D. N.; Phifer, F. M., and Culver, H. B.: Horseshoe Kidney, *Ann. Surg.* 82:735-764 (Nov.) 1925.

sistently found in the duodenum of the dogs of our series. If anaerobic cultures had not been made, 32 per cent instead of 4 per cent would have been considered sterile.

One is struck by the high counts in four of this series of normal dogs. We cannot explain this inconsistency except to suggest that in some way or other there was a high intake of bacteria just before operation. There is a possibility that the dogs were fed, although the caretakers deny this, and no food was found in the stomach at operation. It is significant that these animals were all operated on within a single week. It is possible that they were a poorly nourished group. With these exceptions, the bacterial count of the normal duodenum of our dogs was low.

TABLE 1.—Results of Duodenal Obstruction in Dogs.

Num- ber	Laboratory Num- ber	Before			Day P.O.	Degree of Ob- struc- tion	Second Operation			Day P.O.	Degree of Ob- struc- tion	Third Operation			Day P.O.	Degree of Ob- struc- tion	Fourth Operation		
		+C	-B	+B			+C	-B	+B			+C	-B	+B			+C	-B	+B
1	8081	0	1	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
2	8097	0	0	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
3	8098	0	1	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
4	8103	0	0	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
5	8104	0	0	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
6	8105	4	1	0	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
7	8110	0	0	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
8	8126	1	1	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
9	8125	1	0	1	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
10	8147	1	0	0	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
11	8159	1	1	0	..	.....	..	..	..	..	.....	..	..	..	..	.....	..	..	..
12	8190	2	0	0	17	+	0	2	1	81	++	4	4	4	110	++	5	5	4
13	8191	3	0	2	17	++++	5	5	4	77	++++	4	4	4	121	++++	1	4	3
14	8201	1	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	8202	1	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	8209	1	1	1	10	+	1	0	2	70	++	4	4	4	110	—	5	4	2
17	8205	0	0	0	39	++	6	3	6	108	++	5	6	4	—	—	—	—	—
18	8213	0	1	0	35	++	3	3	3	—	—	—	—	—	—	—	—	—	—
19	8214	0	0	2	37	+++	0	4	4	89	+++	2	5	2	—	—	—	—	—
20	8222	5	3	5	49	++	5	5	5	70	+++	5	5	5	—	—	—	—	—
21	8223	0	0	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	8269	5	7	7	49	++	5	7	6	79	++++	7	7	6	—	—	—	—	—
23	8261	5	7	7	45	++	6	6	4	80	++++	7	7	4	—	—	—	—	—
24	8334	3	5	3	45	++	6	9	7	79	++++	2	5	5	—	—	—	—	—
25	8417	0	0	1	39	++++	5	0	5	63	++++	6	5	4	—	—	—	—	—
26	8418	—	—	—	32	+	0	0	3	61	++	5	5	4	—	—	—	—	—

In this table and in table 2, 0 indicates no growth; 1, from 1 to 100 per cubic centimeter; 2, from 10 to 100 per cubic centimeter; 3, from 100 to 1,000 per cubic centimeter; 4, from 1,000 to 10,000 per cubic centimeter; 5, from 10,000 to 100,000 per cubic centimeter, etc. ++, slight dilatation; +++, moderate dilatation; +++, marked dilatation; +++, extreme dilatation. +C indicates gram-positive cocci; -B, gram-negative bacilli; -B, gram-positive bacilli. Figures in the "Days P.O." column are the number of days after the production of obstruction was present in the duodenum.

Eleven of these animals and one other which did not have an obstruction culture taken, were reexamined after a partial obstruction had existed in degree varying from slight to extensive for from ten to forty-nine days.

In none of the twelve examinations was the gut found sterile. In only one did a single type exist alone, and that was the gram-negative anaerobic bacillus. In six, all three forms were found. The cocci were present in nine and absent in three. The gram-negative bacilli were



nephrosis. Some of these factors were experimentally modified over long periods of time, thus increasing (diuresis) or diminishing (oliguria) urine formation; the effect of such changes on the rate of development of hydronephrosis was noted. The effect of more direct alteration of intrarenal pressure and blood flow was studied. To determine the gross changes in the kidneys, stereoscopic roentgenograms were made after intra-arterial injections of barium sulphate; the capacities of the renal pelves were measured, and the kidneys were then sectioned and studied further. The discussion of experimental results has been summarized under the following heads.

*Splanchnotomy.*—Complete obstruction of a ureter in rabbits was followed by the progressive development of hydronephrosis. The degree of hydronephrotic atrophy was proportional to the duration of the obstruction. Unilateral splanchnic neurectomy caused diuresis on the side of operation as the result of vasodilatation, with an increase in the blood flow through the kidney. This diuresis persisted for long periods. Unilateral interruption of the splanchnic supply after complete ligation of the ureter had no influence on the rate of development of the hydronephrosis.

*Partial Obstruction of the Renal Artery.*—In this group of experiments, the renal artery was partially compressed and permanent unilateral oliguria produced by diminishing the blood flow and intrarenal blood pressure. It was noted that: 1. Urinary secretion could be reduced by a properly placed, partially obstructing rubber tube on the renal artery. 2. With the blood flow and the intrarenal blood pressure reduced and the ureter on the same side totally ligated, hydronephrosis developed to a much greater degree and more rapidly than when the ureter alone was ligated. 3. The increase in the rate of development of hydronephrotic atrophy in the presence of reduced secretory pressure and of pressure atrophy are important factors, but the nutritional factor is an equally or more potent one in the production of hydronephrosis. 4. Rapid parenchymal degeneration resulting from anemia by arterial compression weakens resistance and accelerates dilatation, in spite of the diminution in back pressure.

*Partial Constriction of the Renal Vein.*—The effect of diminished blood flow, caused by partial obstruction of the renal vein, but with

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A. B.: Experimental Hydronephrosis: The Effect of Changes in Blood Pressure and in Blood Flow on Its Rate of Development: II. Partial Obstruction of the Renal Artery: Diminished Blood Flow; Diminished Intrarenal Pressure and Oliguria, Arch. Surg. 11:649-659 (Nov.) 1925. Hinman, Frank, and Hepler, A. B.: Experimental Hydronephrosis: The Effect of Changes in Blood Pressure and in Blood Flow on Its Rate of Development, and the Significance of the Venous Collateral System: III. Partial Obstruction of the Renal Vein Without and With Ligation of All Collateral Veins, Arch. Surg. 11:917-932 (Dec.) 1925.

## COMMENT

Certain of our observations corroborate the work of previous observers. Aerobic bacteria were present in the majority of duodenums of our normal dogs for a considerable length of time after the passage of food through the duodenum. With anaerobic organisms also considered, it was found that the duodenum was rarely sterile. The viable bacteria were enormously increased in number after chronic or partial obstruction of the duodenum which produces a delay in the passage of intestinal contents and some degree of distention and hypertrophy of the gut above the obstruction. This relative increase in the viable organisms in the stripped gut was striking, but attention should be called to the fact that the dilated lumen filled with material made the actual increase even greater. The amount of fluid probably did not vary more than three or four times the estimated quantity in any case, while the number of bacteria per milliliter increased thousands of times. This increase is probably caused by a multiplication of the bacteria in

TABLE 2.—*Results of Duodenal Obstruction in Dogs Shown After A Third or Fourth Examination*

Number	Laboratory Number	Number of Operations	Day of Obstruction	Degree of Obstructions	Above			Below		
					+C	-B	+B	+C	-B	+B
1	8190	4	119	+++	5	5	4	5	5	5
2	8191	4	121	++++	1	4	3	5	5	5
3	8209	4	119	++	3	3	1	5	5	5
4	8205	3	108	++	3	6	4	1	7	7
5	8314	3	80	+++	2	3	2	1	5	5
6	8332	3	70	+++	5	6	5	1	5	4
7	8369	3	59	++++	3	3	6	0	0	0
8	8361	3	89	+++	7	7	4	5	4	5
9	8364	3	79	+++	3	5	5	5	5	1
10	8117	3	63	++++	0	5	4	0	5	5
11	8118	3	66	++	5	6	4	4	7	5

the duodenum. Any delay of food in the stomach favors a great destruction of bacteria, but when the food mass has passed the pylorus, it comes in contact with the duodenal fluids which have a much weaker antiseptic action.

The great variability of the flora from time to time in animals with duodenal obstruction, with a predominance of now one and now another type, suggests that the bacteria are constantly changing, and that this variation depends on the intake and survival of the different types of bacteria rather than on the variance of the local conditions. But there is some evidence that the conditions tend to favor the predominance of the gram-negative organisms. When bacteria are growing together in large numbers, the question of their interaction becomes an important one. In a number of instances there seemed to be an inhibition of the growth in the test tube of the gram-positive anaerobic bacilli cultured from our animals by the gram-positive aerobic cocci. The typical

monia, one each from uremia, tuberculous meningitis, miliary abdominal tuberculosis, and general peritonitis. In seven (5.8 per cent) of the 121 cases death was considered due to operation. Krönlein reports 5.6 per cent, Zuckerkandl 7.7 per cent, and Wildbolz 2.8 per cent mortality in their series of operative cases. Thirty-six of Westerborn's patients died later from tuberculosis or other renal disease, a mortality of 33.6 per cent; the total mortality (forty-three deaths in 114 cases) was 37.8 per cent. The following were the causes of death: renal tuberculosis in sixteen cases; pulmonary tuberculosis in nine; multiple foci in two; miliary tuberculosis, tuberculous meningitis in four; renal disease in five; operation in seven, and intercurrent disease in two.

Only forty-seven of the 111 patients for whom complete data were obtainable are living and without symptoms of renal tuberculosis. Males are more likely than females to have trouble after operation. This may possibly be due to the frequency of genital infections in men, although from the mortality results associated genital infection apparently produces increased immunity to the infection. Forty-four per cent of patients with associated genital tuberculosis got well; in contrast only 35 per cent of patients without such genital infection recovered. Forty per cent of the men and 73.2 per cent of the women are completely cured; 13 per cent of the men are still having trouble, while all the women living are free from trouble; 47 per cent of the men and 26.8 per cent of the women died. Bilateral tuberculosis occurred in thirteen of the entire number of cases.

[ED. NOTE.—In the large series of cases reported from ten to twenty years ago, the operative mortality following nephrectomy was high. Von Schmieden reported a mortality of 25.4 per cent. In 106 cases in which operation was performed between 1890 and 1900, Küster (1902) found a total mortality rate of 18.8 per cent in 297 compiled cases. In recent large series of cases, the percentages are much lower: Boeckel reports 5.8 per cent, and Legueu and Chevassu 5.9 per cent. Israel, in a review of 1,023 cases of nephrectomy, found an operative mortality of 12.9 per cent, and a late mortality rate of from 10 to 15 per cent. Wildbolz asserts that the larger general reviews are not of so much value as the more carefully compiled statistics of individual surgeons. From the reports from several large urologic centers, he reviewed 1,450 cases in which the mortality rate was 5 per cent. Only eleven (2.4 per cent) of 445 of Wildbolz' own patients died following operations. Most of the deaths were due to cardiac or pulmonary complications. Sixty-two per cent of 317 patients operated on at least one year before were cured; 30 per cent were dead, and 8 per cent still had evidence of disease. Fifty-five per cent of 104 patients operated on at least ten years before were completely cured; forty-four died from tuberculosis, mainly of the genito-urinary tract. In Kummell's 188

cocci group and in 40 per cent members of the *B. coli* group were present. Thus the anaerobic gram-positive bacilli were the most consistent but were not invariably present.

2. After partial obstruction of the duodenum, these organisms were found in enormously increased numbers varying with the degree of obstruction and the extent of dilatation of the intestine above the obstruction. The greatest increase in numbers was with the bacilli of the *B. coli* group, but there was no striking difference between this and the other types.

3. This increase was maintained for a considerable period, but in some cases there was a decrease later, even though the obstruction persisted.

4. The flora of the duodenum in any particular animal was not constant, now one and now another type predominating.

5. The gut immediately below the obstruction was usually more or less collapsed. In more than half of the cases of this series, there were fewer viable organisms in the lower jejunum far below the obstruction than in the gut just above the obstruction.

concludes that catheterization through an opened bladder should not be attempted on account of its uselessness in cases in which cystoscopic ureteral catheterization is unsuccessful. A good "constante d'Ambard" associated with satisfactory exploration of the presumed healthy kidney will be a safeguard against excision of the diseased organ. Michon suggested the use of MacCarthy's urethroscope with injection of indigo-carmin in order to detect the ureteral orifices when cystoscopic catheterization is impossible. If the ureteral catheter is stopped shortly after it enters the ureters, he advises catheterization through a cystostomy opening; this should be successful if one takes care to lift up the inter-ureteral muscle with forceps. Marion favors catheterization through the open bladder, stating that the cystostomy and drainage at least gives relief to the patient. Pasteau also states that when cystoscopic catheterization is impossible, catheterization through an open bladder is easily performed and should always be done. Legueu agrees with Darget and states that one may be unsuccessful in attempting to catheterize through an open bladder. Nephrectomy in those cases may be performed after exploration of the healthy kidney. He cites his statistics of 1,209 cases of renal tuberculosis. In 1,053 in which operation was performed after catheterization, the mortality rate was 1.9 per cent; in 341 cases in which operation was not preceded by catheterization, the mortality rate was 3.9 per cent. Pasteau and Marion do not believe in the safety of nephrectomy performed without preliminary catheterization and only based on the "constante d'Ambard."

[ED. NOTE.—When tuberculous infection of the kidney has advanced to such a degree that it is impossible to determine the side of the primary lesion definitely by cystoscopic procedures, it is probable that bilateral infection is present. In some cases it is extremely difficult to rule out the possibility of bilateral infection; one kidney may obviously be diseased while the opposite kidney reveals little evidence of infection. In a series of twenty-two cases at the Mayo Clinic of apparently unilateral tuberculosis, guinea-pigs were inoculated with urine from the supposedly healthy kidney. The results were positive for tuberculosis in seven, and negative in fifteen. In every case two or more guinea-pigs were injected, so that the results may be regarded as fairly accurate. Even with infection in both kidneys, the condition of the bladder may not be any different from its condition in ordinary areal cystitis, and bilateral tests often show that renal function is normal and equal. Pyelography may demonstrate a moderate degree of inflammatory dilatation like that observed with chronic pyelonephritis. Often, however, evidence of cortical necrosis confined to one or more calices will reveal the tuberculous origin. In some of these cases cultures made from the urine from the kidney may show the presence of colon bacilli, which is particularly misleading since the bacteria of secondary infection are not



from 16 to 50 years of age. About one-sixth of the general population, that is, about 17 per cent, are more than 51 years old. In his series 122 (7.8 per cent) were between the ages of 51 and 75, and of this number four were between 71 and 75.

Blatt<sup>11</sup> reports a series of cases of open cavernous tuberculosis. This type of case is often seen, and it is the opposite of the occluded condition as described by Zuckerkandl and Braasch. Wolff reported eighty-eight cases of occluded renal tuberculosis, the distinguishing feature of which is complete isolation of the kidney from the bladder by stricture of the ureter. Blatt found five cases of open, cavernous, renal tuberculosis without vesical symptoms in a series of 130 cases treated operatively. He believes that this type of lesion, the bladder not being involved, is caused by an unusual strain of the bacilli of tuberculosis that affects the kidney alone.

Perret<sup>12</sup> describes his technic of nephrectomy. His experience with a series of cases without a death included eighty-seven in which nephrectomy was performed for tuberculosis. Perret does not use the oblique incision, but the high transverse lumbar. He believes, with Bazy, that the incision must first of all facilitate the most dangerous and important step of the operation. In cases of nephrectomy, this step is represented by the freeing of the superior pole and the preparation, ligature and cutting of the vascular pedicle; the ureter is not severed as is often thought. The incision is extended up to the lateral border of the quadratus lumborum; a tube should be placed there to drain the inferior culdesac of the renal pouch. If after complete cicatrization of the wound, a secondary abscess forms around the ureter, it will penetrate through the muscle layers. During the "décollement," or liberation, the kidney should be left in place without handling, as most of the immediate complications of nephrectomy, such as tuberculous meningitis, miliary dissemination, reflex anuria, embolism and infection of the wound, are caused by unnecessary maneuvers which traumatize the kidney and cause traction on its pedicle. Perret does not attempt to remove a large section of the ureter. He removes only 5 or 6 cm., believing that, if an abscess does form around the severed stump of the ureter, it had better be high in the wound, in a drained area, rather than low, in the pelvis.

Perret does not drain with rubber drains and gauze, as the latter becomes adherent to muscle and peritoneum, functions poorly and is painful to the patient. For more than fifteen years he has used a glass drain, which is replaced by thinner ones on the fifth and tenth days. In this way a firm canal of fibrous tissue forms, through which a sec-

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11. Blatt, Paul: Offene kavernöse Nierentuberkulosen ohne Blasensymptome, *Arch. f. klin. Chir.* 140:654-662 (May) 1926.

12. Perret, C. A.: Contribution a la technique de la nephrectomie (en particulier pour tuberculose renal), *J. d'urol. méd. et chir.* 21:397-412, 1926.

ostium on each side as a part of cystoscopic routine is emphasized. The hurried examination of the vesical mucosa and failure to carry out indigo-carmin tests of function in cases of suspected double ostium, as well as the omission of urography, account for the failure to recognize many of the cases. The fault lies with the cystoscopist who overlooks such conditions.

[ED. NOTE.—It is a commendable routine to look over the surrounding area of the bladder, the trigon and the sphincteric region for second openings. The value of pyelography in demonstrating this anomaly cannot be stressed too much. If a unilateral pyelogram seems incomplete and the pelvis small in relation to the renal shadow, or if certain calices are apparently missing from the upper or lower pole, the possibility of a second pelvis or ureter should be borne in mind, and further search for a second ureteral orifice should be made. The most common anomaly in the urinary tract is duplication of the renal pelvis and ureter; such duplication may be unilateral or bilateral, complete or incomplete. An excellent review of 300 cases, largely from the literature, is given by Mertz in a recent series of articles. It is of interest that in 27 per cent of these the duplication was bilateral.

The comparatively large number of cases of bilateral duplication which have been reported in the literature may be explained by the fact that this unusual condition is reported, while the more ordinary unilateral condition is not. The comparatively common occurrence of ectopic ending of the duplicated ureter as reported in the literature probably is also exaggerated and can similarly be explained.

The incidence of pathologic complications and surgical lesions is high. The most common lesion requiring surgical treatment is hydronephrosis, caused usually by the obstruction of one ureter. Whether or not this occurs at the point where the ureters cross one another and is the result of this crossing, as suggested by Pawloff, has not been definitely proved. It seems probable, however, that in some cases the ureteral obstruction is the result of stricture due to congenital anatomic defect. In some cases stricture in the lower ureter is associated with marked dilatation of the ureter above, comparatively little dilatation of the renal pelvis itself and marked cicatricial pyelonephritis in the peripelvic renal tissue. In cases of extensive hydronephrosis, the surrounding tissues usually become atrophied, and the infection may spread to the other renal segment.

Chronic tuberculosis confined to one pole of a single kidney, if the lesion is caseated or fibrous and walled off from the remaining apparently normal renal tissue, may easily be confused with tuberculosis which affects one segment of a double kidney. The pelvis of the diseased segment may be obliterated and the ureter be atrophied or involved in



In both the renal pelvis and the ureter, the individual papillomatous fronds are shorter and broader than similar growths in the bladder; there is more extensive fusion of adjacent fronds, and atypical cell masses are more often seen. Histologically, the growth in the ureter and pelvis contains more areas undergoing malignant degeneration than the comparatively more villous transplants in the bladder, and loss of cellular polarity and regularity, with the presence of numerous mitotic figures, may occur in a grossly benign tumor, as in papilloma of the bladder. In certain cases, the histologic difference in the tumors in the bladder, ureter and renal pelvis is only slight. Lower reported a case in which sections from the kidney, ureter and bladder were histologically similar.

The majority of papillary tumors of the renal pelvis are histologically similar to the malignant papillomas, or the papillary epitheliomas occurring in the urinary bladder. In an occasional case glandular changes have been noted in cells of the papillary structure. If a careful histologic study is made of sections from various parts of tumors of the renal pelvis, small circumscribed areas of malignancy will almost invariably be found, even in the small pedunculated grossly benign papillomas.]

*Leukoplakia*.—Karo<sup>16</sup> reported a case of leukoplakia of the kidney, pelvis and ureter before the Berliner Urologische Gesellschaft. He stated that the case was of eight years' duration and that the leukoplakia formation was on the basis of an infection by the colon bacillus.

[ED. NOTE.—Leukoplakia has long been a subject of interest and conjecture because of its unknown etiology and pathologic significance. The occurrence of such a process in the urinary tract, reproducing exactly the microscopic and gross appearance of skin, together with its relative rarity, have stimulated its study constantly. The urinary tract is derived from entoderm and mesoderm, whereas leukoplakia is an epithelial process. Hinman, Kutzmann and Gibson,<sup>17</sup> in a study several years ago, concluded that leukoplakia played a definite rôle in the development of squamous-cell carcinoma of the urinary tract. A review of the existing theories suggested that leukoplakia was possibly a true metaplasia on the basis of chronic inflammation and irritation, or the biologic process of adaptation to environment in the form of protective cornification. It was also thought that leukoplakia of the urinary tract might arise on the basis of misplaced embryonal rests of primitive ectoderm.

Clinically, the symptoms are those of infection of the urinary tract, urinary lithiasis or conditions with which they may be associated. It

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16. Karo, W.: Leukoplakie des Nierenbeckens und Ureters, Ztschr. f. Urol. 20:208-211, 1926.

17. Hinman, Frank; Kutzmann, A. A., and Gibson, T. E.: Leukoplakia of the Kidney Pelvis, Surg., Gynec., and Obst. 39:472-489 (Oct.) 1924.

The diagnosis of horseshoe kidney may be determined by palpation. Since the advent of urography, diagnosis by palpation is less frequent. Roentgenographic evidence consists of the close proximity of one or both renal shadows to the spine at a lower level than normal, and the close proximity of shadows of renal calculi to the spine, or the obliquity of their position in relation to it. If, however, one or both halves are symmetrical, that is, at the same level and as far away as the normal kidney, the roentgenographic data are of little help. Pyelography is the method that corroborates the suspicions aroused by the roentgen-ray observations. If one or both pyelograms lie in close proximity to the spine at the same or different levels or even extend partly across the spine, there can be little or no doubt of the presence of horseshoe kidney. Braasch called attention to the finding of one or more calices directed mesially, long narrow pelves, and the unusual course of the ureter passing behind the calix and not entering the pelvis along its convex border.

Eisendrath, Phifer and Culver recommend the extraperitoneal route in operating. It is frequently necessary to extend the incision to the outer border of the corresponding rectus muscle because access to the pelvis must be from the ventral and not from the dorsal aspect, as in ordinary pyelotomy. The peritoneum may be displaced while the patient is in the lateral position, and then the patient may be placed in a supine position while the pelvis and isthmus are being explored. For heminephrectomy a good exposure is essential owing to the many accessory vessels that enter the hilum, poles and isthmus in an irregular manner. The isthmus may be clamped as one proceeds to divide it, and the denuded areas closed by mattress sutures of chromic catgut reinforced at loop and knot by fat pads.

[ED. NOTE.—This is an excellent review of the anatomic, pathologic and surgical features of an anomaly that has been much discussed in American and European literature during the last five years. The importance of correct diagnosis, which can usually be made by the proper application of urologic methods, is to be emphasized. The authors contribute little that is really new to our knowledge of the condition, but in a clear way they have epitomized the essential practical features of its pathology.]

*Hydronephrosis.*—Hinman and Hepler,<sup>6</sup> in a comprehensive set of experiments, have undertaken to determine the causal relation between some of the recognized factors in the formation of the urine and hydro-

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6. Hinman, Frank, and Hepler, A. B.: Experimental Hydronephrosis: The Effect of Changes in Blood Pressure and Blood Flow on Its Rate of Development: I. Splanchnotomy: Increased Intrarenal Blood Pressure and Flow; Diuresis, Arch. Surg. 11:578-585 (Oct.) 1925. Hinman, Frank, and Hepler,

individual cysts, thus permitting the kidney to return, at least partially, to its normal size. The cysts usually do not contain urine, and permanent fistulas do not form.

Begg,<sup>21</sup> after a brief review of the literature on the subject of hemorrhagic cysts of the kidney, adopts the description of Brin, who reports twelve cases. This description is as follows:

The cysts are solitary, and their size as a rule is large. Their extirpation is difficult on account of adhesions to the surrounding organs. The cyst wall is whitish, and the contents consist of red or blackish fluid with old brownish clots. The latter may be black in color, or they may be of white fibrin. The cavity of the cyst is received into the rest of the kidney substance as an egg into an egg-cup. Its wall is continuous with the outer surface of the kidney, without any obvious ridge of demarcation. The internal surface of the cyst wall is irregular and festooned with clots, of which the most superficial are of a dark red or blackish color, and the deepest, grey-white, formed of fibrin, and intimately adherent to the fibrous lining of the cyst. The wall is always much thicker than in the case of the simple serous cysts, and may reach 5 mm. or even 1 cm. in width.

Microscopically, three layers can be distinguished: (1) an inner layer of clots and fibrin; (2) a middle fibrous layer, and (3) an outer layer formed by renal parenchyma atrophied and sclerosed.

Both the part of the kidney containing the cyst and the rest of the organ are clothed in a fibrous capsule of normal thickness. There is rarely a communication with the kidney pelvis.

These cysts are not ordinary serous cysts into which hemorrhage has occurred. Large solitary hemorrhagic cysts are rare. They have few characteristics in common with solitary simple cysts and should be placed in a separate category. They are different in nature from blood cysts caused by the degeneration of malignant tumors, from hematonephrosis and from traumatic pararenal cysts. The suggestion is made that these cysts are of the nature of localized hematonephrosis, in which the source of the bleeding remains active for a long time. This source may be in the papillae of the affected portion of the pelvis, and in the case reported an angioma was demonstrated. In some instances the cyst may owe its origin to an angioma in the substance of the kidney itself.

The diagnosis is obscure, and the treatment is total nephrectomy.

*Lithiasis.*—Hinman and Gibson<sup>22</sup> report a case of recurring urinary lithiasis in a physician. Left nephrectomy had been performed because of calculous pyonephrosis, and several operations had been performed on the right kidney because of rapidly recurring stones. This kidney, because of the repeated attacks of stones and infection, was practically destroyed, leaving what appeared to be less functioning renal tissue than is necessary to maintain life. Death was due to cardiac failure and not to uremia. The important points of the case were the rapidity of recur-

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21. Begg, R. C.: Solitary Hemorrhagic Cysts of the Kidney: With Report of a Case Originating in a Cavernous Hemangioma, *Brit. J. Surg.* 13:649-655 (April) 1926.

increased intrarenal pressure and oliguria, on the rate of development of hydronephrosis is considered in this group of experiments. Partial constriction of the renal vein causes capillary stasis and increase in glomerular pressure. The chief question was whether the latter could so affect secretory pressure as to increase the rate of development of hydronephrosis. Prolonged partial obstruction of the renal vein not only produced diminution of blood flow through the kidney and oliguria, but also increased the intrarenal pressure and, if the degree of obstruction was not too great, increased secretory pressure. When such a procedure was combined with complete ureteral obstruction on the same side, the usual course of development of hydronephrosis was accelerated up to twenty-one days, after which the rate of development followed the type usually seen in the longer periods in simple hydronephrosis. The venous stasis of the early periods was found to be nullified later by the compensatory action of the perirenal collaterals. When the collateral venous system was completely destroyed by ligation, and then partial constriction of the vein combined with complete ureteral obstruction, the rate of development was found to be accelerated for the early periods of hydronephrosis over that even of a simple venous constriction. After twenty-eight days marked shrinkage or secondary atrophy occurred, owing to the marked venous occlusion as a result of failure of a collateral system. The action of the venous collateral system, therefore, was compensatory, and its development or nondevelopment was not an essential factor in simple hydronephrosis. Its failure may therefore be an important one in the rare instances of late secondary atrophy with venous constriction. The initial acceleration in the rate of development of hydronephrosis that occurred with venous constriction was primarily the result of increased secretory pressure, and only secondarily the result of the nutritional disturbance.

*Tuberculosis.*—Westerborn<sup>7</sup> reports the cases of renal tuberculosis treated at the Upsala University Clinic in Sweden from 1901 to 1923. In all there were 151 patients; 100 were males and fifty-one females; 126 were less than 40 years of age. In 121, nephrectomy was performed; in sixty-five, the right and in fifty-six, the left kidney was removed. Complete data were obtainable in 111 of these 121; sixty-six of the patients are living, and forty-five are dead. Two died from intercurrent disease; the remainder died from renal tuberculosis or renal disease. Six died the first month, six from two to six months, and five from six to twelve months after operation; four lived more than ten years. Of the six patients who died the first month after operation two died from pneu-

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7. Westerborn, Anders: Das Resultat der Behandlung der Nierentuberkulose in der chirurgischen Universitätsklinik zu Upsala, insbesondere mit Rücksicht auf die Entstehung von Miliartuberkulose nach Cystoskopie und Sondierung, Arch. f. klin. Chir. 139:699-728. 1926.

cases of papillitis or pyelitis granularis. When there is marked glomerulonephritis, decapsulation is of value. When the bleeding is massive and threatening to life, nephrectomy, or possibly decapsulation, is the procedure of choice. Nephrotomy is discouraged.

Gottlieb feels that the term "bleeding from a node or focus" is a better one than "essential hematuria."

[ED. NOTE.—Essential hematuria still remains a discouraging field for study in urology. Certainly, the pathologic changes found are not consistent nor are they clinically or anatomically demonstrable beyond a doubt. Gottlieb's study, while thorough and interesting, adds little that is really new or tangible. It is probable that for some time to come we shall await new evidence concerning the causes of this obscure disease.]

*Renal Function.*—Hélouin<sup>24</sup> says that most urologists have abandoned the intramuscular phenolsulphonphthalein test and use only the intravenous method. He used the latter more than a hundred times without accidents or trouble. The duration of the test is sixty minutes; 3 mg. of phenolsulphonphthalein is diluted with 4 cc. of sodium chloride solution and injected into a vein. The urine is first collected after thirty minutes and again thirty minutes later. The average elimination in normal cases has been: after thirty minutes, from 50 to 60 per cent; during the next thirty minutes, from 18 to 25 per cent, and during the whole hour, from 65 to 85 per cent. Hélouin's work on phenolsulphonphthalein concerns principally its relative value to the "constante d'Ambard" or "K." He concludes that the intravenous phenolsulphonphthalein test and "K" usually give similar results, but from a quantitative point of view one observes differences fairly often which should not be neglected. In general, the test which should serve as a criterion for the evaluation of the individual renal function should be the one showing the poorest return. The phenolsulphonphthalein test should be used instead of "K" only in cases in which it is materially impossible to perform the latter; but, on the other hand, the results of "K" should always be controlled by a phenolsulphonphthalein test. Both tests complement each other, and their individual clinical value increases when they are studied together.

[ED. NOTE.—Ambard's coefficient is still sponsored by a number of internists and urologists, particularly in France. It is interesting to note that it is gradually being replaced by the much simpler and more accurate phenolsulphonphthalein test.]

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24. Hélouin: L'épreuve de la phénolsulfonephthalène intraveineuse dans l'exploration fonctionnelle rénale. *Presse méd.* 1:755-756 (June 16) 1926.

cases, there was a mortality rate of 7 per cent; of the remaining patients, sixteen died the first year, and fourteen in the next four years. Thirty-nine patients were well from fifteen to twenty years after operation, and thirty-eight from ten to fifteen years.

Twenty-three (2.7 per cent) of 845 patients subjected to nephrectomy for renal tuberculosis at the Mayo Clinic died during the first month after operation. In the earlier cases uremia was the most common cause of death and accounted for the large operative mortality. With the present accuracy of preoperative diagnosis, uremia only rarely causes death. When death occurs following operation from uremia, it is usually due to nontuberculous infection of the opposite kidney, or to chronic nephritis. The common causes of early death after the removal of tuberculous kidneys are peritonitis and pulmonary complications, such as empyema, pneumonia and pulmonary embolism.

Israel believes that the chief causes of late postoperative death are pulmonary tuberculosis and tuberculous infection of the opposite kidney. He found, in a series of cases, that more than one-half of all late deaths occurred within two years after nephrectomy. Pulmonary tuberculosis was the cause of death in 45 per cent, tuberculosis of the kidney in 35.9 per cent, and acute miliary tuberculosis in 14 per cent. He also believes that pulmonary tuberculosis existed before operation in 73 per cent of the cases in which it caused death. Meningitis is often the cause of late death. Simmonds found at necropsy that 30 per cent of men with genito-urinary tuberculosis had died from meningitis, only 5 per cent from pulmonary tuberculosis, and none from infection of the genito-urinary tract.]

Darget<sup>8</sup> reported the following case, which has been the source of a long discussion at the Société française d'urologie. A man, aged 51, who had had renal tuberculosis for the last six years, was examined on account of increased frequency and pyuria. The right kidney was enlarged and painful; the left could not be palpated. The "constante d'Ambard" was 0.1, the blood urea 0.35 Gm. and the urine urea 16.2 Gm. Numerous attempts to catheterize the ureters were made, with all possible artifices (epidural anesthesia with morphine; constant irrigation and spinal anesthesia) but none was successful. The capacity of the bladder would not exceed 25 to 30 cc., and the ureteral orifices could not be found. Renal function being good, cystostomy was performed in order to catheterize the ureters, but this also was unsuccessful. Suprapubic drainage was maintained, and the healthy left kidney was explored operatively before excision of the right. Cure followed, although the closure of the cystostomy opening was difficult. Darget

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8. Darget, R.: Tuberculose renale ancienne: Impossibilité de catheterisme ureteral par voie cystoscopique et a vessie ouverte: Nephrectomie sur la constante apres lombotomie exploratrice, J. d'uroł. méd. et chir. 21:367-374, 1926.

## LITERATURE

In the reported cases there is throughout a relative consensus of opinion either that these tumors are malignant, but in a relatively low degree, or that, even if benign, they may undergo carcinomatous change. This fear has caused the surgeon to perform an extensive operation for their removal, after which he has given a good prognosis, since they were supposed to be "cancer of a relatively low grade of malignancy."

The early authors considered all these tumors as cancers, while the English writers, Williams,<sup>1</sup> Bryant,<sup>2</sup> Shield<sup>3</sup> and others, differentiated the benign, intracystic papillomas. However, there is still much confusion, and mistaken diagnoses, which class the benign cases as cancer, are still frequent.

Ewing<sup>4</sup> holds that malignant forms are relatively common, but says that the lymph nodes may remain immune for an indefinite period. Delbet thinks malignant forms are sufficiently common to justify radical treatment in all cases. According to Upcott,<sup>5</sup> from four to five out of every ten cases are malignant. Greenough and Simmons<sup>6</sup> class three out of their twenty cases as cancer. In one case clinically malignant, death from cancer followed a radical operation. In another, with nothing in the clinical report to suggest cancer, the patient was well one year after simple removal of the breast; the third patient, in whom the tumor was beneath the nipple and adherent to the skin, was well two years after removal of the breast alone.

Evans<sup>7</sup> says that a nipple discharge in a nonlactating breast is associated with a papillary growth, either intracystic, when it may be a "duct carcinoma," or protruding, when it is the less dangerous "duct papilloma." Murphy<sup>8</sup> reports a case in which there was a villous growth arising from an otherwise smooth-walled cyst. The cut surface of the solid portion of the tumor was encapsulated and apparently situated on the side of the cyst wall from which the papilloma arose. He believed the condition to be suggestive of a low grade of malignancy and treated it as carcinoma, dissecting out the axillary glands. In these no metas-

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1. Williams, W. R.: *A Monograph on Diseases of the Breast, Their Pathology and Treatment, with Special Reference to Cancer*, London, J. Bale and Son, 1894.

2. Bryant, Thomas: *The Diseases of the Breast*, London, Cassell & Co., 1887.

3. Shield, A. M.: *A Clinical Treatise on Diseases of the Breast*, London, Macmillan Company, 1898.

4. Ewing, James: *Neoplastic Diseases; a Treatise on Tumors*, Ed. 2, Philadelphia, W. B. Saunders Company, 1922.

5. Upcott, H.: *Practitioner* 91:14-18, 1913.

6. Greenough, R. B., and Simmons, C. G.: *Ann. Surg.* 45:188, 1907.

7. Evans, J. H.: *Practitioner* 91:7, 1913.

8. Murphy, J. B.: *Surg. Clin., Philadelphia*, 3:569-574, 1914.

often found in the culture, from a tuberculous kidney. Microscopic examinations and inoculation of guinea-pigs with the urine obtained from either kidney may be negative. However, if repeated attempts are made to stain the catheterized urine, an occasional acid-fast bacillus may be demonstrated, although this may necessitate the examination of many slides.

Deformity of the bladder and the pathologic changes in the mucosa in cases of renal tuberculosis frequently make the cystoscopic technique more difficult than with any other lesions of the urinary tract. In spite of the progressive improvement in our cystoscopic technique, the great aid offered by sacral anesthesia, and the use of indigo-carmin and cystography, cystoscopic technique occasionally fails to identify or locate the disease. A common source of error is an inflammatory proliferation of the mucosa, or granuloma, which may be so extensive as to simulate epithelioma closely. It is not unusual to observe a patient with a persisting suprapubic sinus, after suprapubic cystostomy performed on the assumption that extensive carcinoma of the bladder was present. The proliferation is usually around the infixed ureteral orifice, although in many instances it extends across the trigone and may invade other portions of the bladder. It often resembles epithelioma so closely in its papillomatous nature and tendency to bleed that the confusion might be justified.]

Condamin<sup>15</sup> studied a series of 172 cases of renal tuberculosis in which there was no extrarenal lesion. Cystostomy resulted in cure in 69 per cent; the operative mortality was 2.9 per cent, and the late mortality was 27.5 per cent. In contrast to this, in a group of 517 cases of both renal and extrarenal tuberculosis, cystostomy resulted in cure in only 47 per cent. Nine per cent of patients with renal and pulmonary tuberculosis died following operation, and only 26 per cent recovered completely. Bone lesions have the least effect on the ultimate results: in 62 per cent of hipbone cases, amputation of bone lesions completely necessary occurred. In 59 per cent of tibia cases, amputation of bone lesions, necessary took place.

Flecken<sup>16</sup> investigated the relationship between age and sex and mortality in 1,577 surgical cases of renal tuberculosis. Complete data were obtained in 1,571 cases: 876 patients (57 per cent), were males and 675 (43 per cent) females. Twenty-four patients were 15 years of age or less. The greatest number of patients, 1,376 (87 per cent), were

5. Condamin: Des cases operables aux reins de la tuberculose par tuberculose miliaire par des localisations tuberculeuses extra-rénales. *J. Chir. Méd. et Chir.* 21:371-39, 1926.

16. Flecken, Gustav: Ueber die Prognose der Nierentuberculose im Hinblick zum Alter und Geschlecht der Patienten. *Deutsche Arch. Klin. Med.* 616, 1926.



were placed in a special group with the diagnosis questionable: one early case because of a lack of microscopic confirmation of the gross diagnosis; in the other four because there was a difference of opinion (under report of cases). Still another early case showing a cancer cyst had to be removed from the malignant group, since it was a squamous cell carcinoma and apparently had arisen from a dermoid cyst.

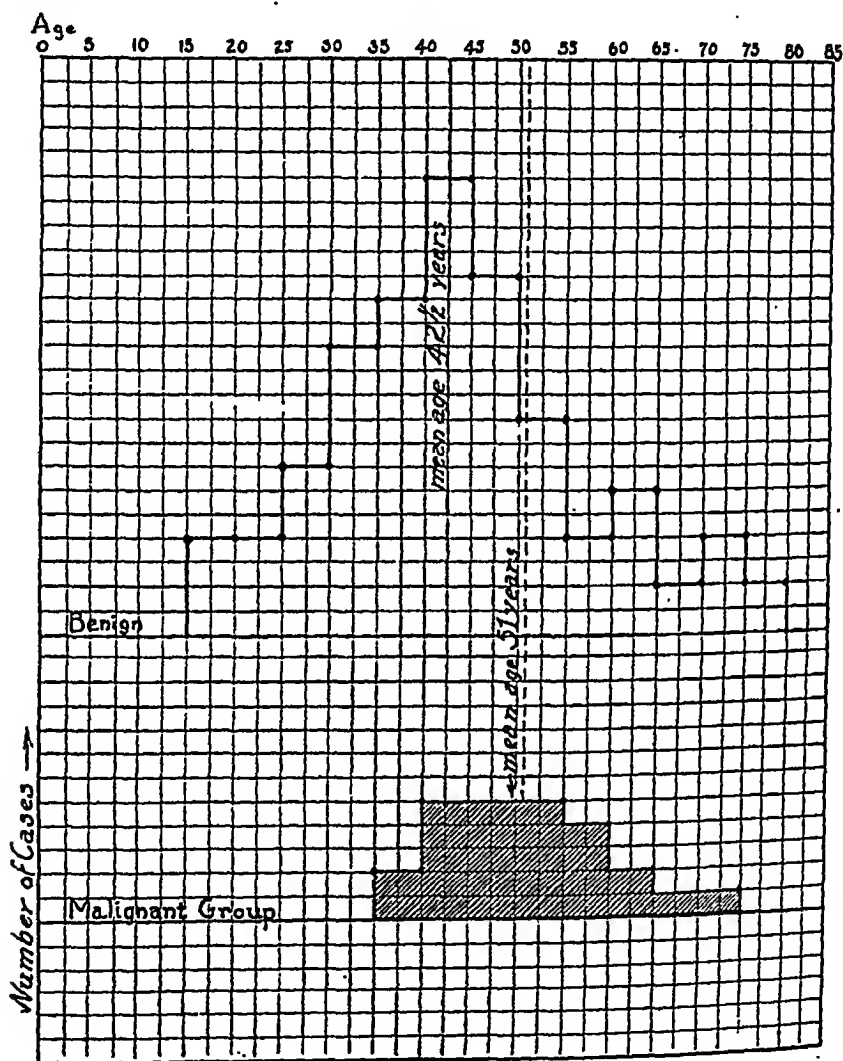


Fig. 1.—Age at onset: actual number of cases occurring in each five year age period. The mean age for the benign group is seen to be 42½ years; for the malignant group 51 years. This chart also shows the large number of benign tumors occurring in patients under the cancer age. Benign group, light; malignant group, shaded; two squares represent one patient.

#### BENIGN GROUP

The following is a composite picture based on ninety-five cases, with a second operation for a similar tumor in nine, giving a total of 104 reports.

ondary abscess may eventually find its way to the exterior. In the past, Perret has catheterized the bladder at the end of the operation; sometimes considerable pus, which has probably come down during the operation, is found in the bladder. If the patient awakes and coughs or vomits, this pus may be forced back into the diseased ureter, and may remove the ligature and infect the wound. The bladder is emptied, washed with warm solution of sodium chloride, and injected with from 15 to 20 cc. of a proprietary form of oil of cajuput.

Joly<sup>13</sup> discusses the question of spontaneous cure of renal tuberculosis and cure by medical means. The question can be concisely summarized. Should the patient be advised to submit to nephrectomy as soon as unilateral renal tuberculosis is diagnosed, or are we justified in trying medicinal treatment first, and only advising nephrectomy if these methods fail? The answer depends on the efficiency of medical methods, and on the dangers incurred by delay. Urologists have answered this question definitely. They are unanimous in advising early operation. In considering the duration of the disease, Joly concludes that the disease is rapidly fatal and destroys life much more rapidly than is usually supposed. Statistics are quoted in support of this conclusion. Rafin found that ninety-one out of 168 patients not operated on were dead, the majority within the first three years after the onset of symptoms. Further, only four of these were found to have died from intercurrent disease. In all, about 90 per cent of patients with renal tuberculosis who are not operated on die from their disease. It is noted that the disease is more chronic in females; this is shown in the duration of the disease, in those dying from it, and in those surviving. This probably is due to the tendency of the disease to involve the genital organs in the male.

In answer to the questions: "What is the condition of the survivors?" "Are they cured?" Joly says,

There is no doubt as to the answer. It is decidedly in the negative. The great majority of the survivors are still suffering from the distressing symptoms of urinary tuberculosis, and in fact, most of them are dying from it. The clinical cures are so rare that they require special mention. They are even so rare that they do not appreciably influence the statistics. We must therefore either look for them in pathological records, or else examine the few isolated cases which have been described as natural cures.

In a careful review of pathologic material, Joly fails to find evidence of actual cure. Cessation of symptoms is more often due to occlusion of the ureter on the affected side or more rarely occlusion of one calix or a portion of the kidney which is tuberculous. In discussing surgical treatment, he finds that 58.9 per cent of his patients are cured, which he notes is strikingly similar to the observations of Judd and Scholl at

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13. Joly, J. S.: The Late Results of Renal Tuberculosis, *Brit. J. Tuberc.* 19:188-195 (Oct.) 1926.

duration of the tumor, nipple discharge and pain ran parallel courses, the number of patients with these symptoms decreasing for the periods of longer duration (fig. 4). The only two variations from this were that ten of the tumors were discovered on physical examination, and the fact that the number of patients with pain falls more rapidly for the periods of longer duration. Only five patients had had pain for more than two years, and none for more than ten years, while the discharge and tumor had been present at times for as long as twenty-five years, with ten and fifteen patients, respectively, giving a history extending over a period of more than two years.

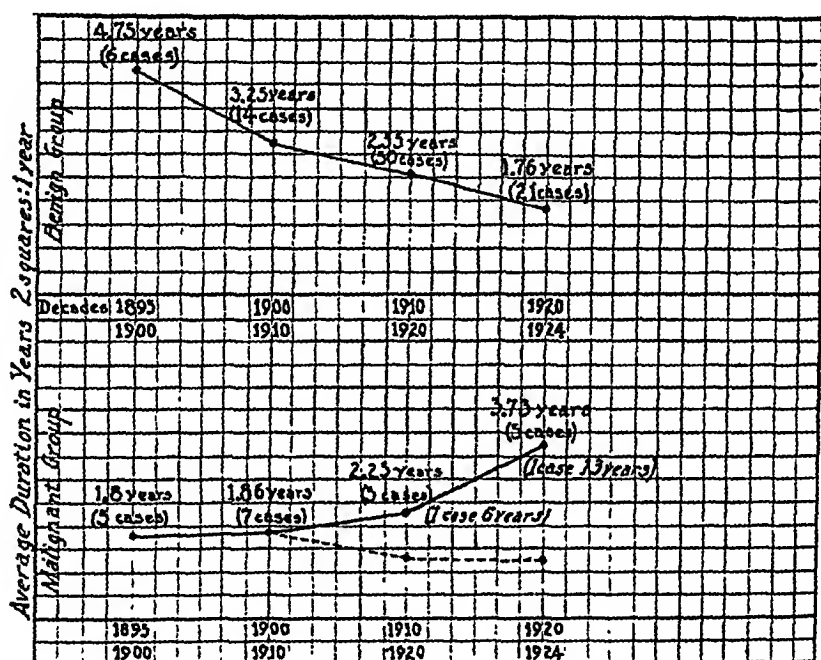


Fig. 2.—Known duration of lesion before operation, showing average duration in years for the cases occurring in each decade; in parentheses are given the number of cases on which this average is based. For the benign group, with the larger number of cases, there is a gradual fall in this curve from the first to the most recent cases. For the malignant group there is a recent increase in the average duration, but this can be seen to be due to one case of long duration in each of the last two age periods. There are so few cases for each decade in this group that the value of these statistics is questionable. Two squares represent one year. Dotted line shows slight fall of duration of cancer cases for recent years if the two cases of six and thirteen years' duration are not included.

*Physical Examination.*—In general the lesion occurred in white women.<sup>11</sup> (two cases in men and eleven in negro women) with predominantly single tumors. (sixty-two of seventy-five cases noted), the

11. In the laboratory the specimens from white predominate over those from colored patients. The exact ratio is difficult to determine.

is almost impossible to diagnose except when cystoscopic examination reveals leukoplakia on the wall of the bladder.

Von Borza<sup>18</sup> states that leukoplakia of the urinary tract is relatively rare. It is usually difficult for the cystoscopist to recognize it in the bladder, while in the kidney it can be diagnosed only at operation or necropsy. Numerous theories are cited, most of which favor metaplasia. The author found only three cases in his clinic in a period of years; two of the cases were diagnosed preoperatively and one at operation. One case occurred in a ureteral stump, nephrectomy having been performed for stone sixteen years previously. In the other two cases the leukoplakia was in the renal pelvis; in one there was a squamous-cell carcinoma of the renal pelvis, and in the other a squamous-cell carcinoma of the bladder. For this reason von Borza believes there is a relationship between leukoplakia and carcinoma. In discussing the histogenesis of leukoplakia, von Borza considers that there is more than merely a local irritative factor; it may be based partially on an embryonic basis and partially on an endocrine basis, hormones being brought forth which influence all growth and changes.

Briggs and Maxwell<sup>19</sup> review eighty cases of leukoplakia of the urinary tract. Forty cases were vesical, twenty-four renal, ten ureterorenal, four ureterovesical, and two renal or ureteral or both. They state that the etiology is not understood and no theory has been proposed that explains the majority of cases; even if always associated with stone or specific infection, the genesis of leukoplakia, which histologically is a metaplasia of tissue, would still not be entirely susceptible of explanation. In summarizing, they state that the renal pelvis is probably oftener affected than the bladder; that it may occur at any age and that it is a chronic condition. There are really no pathognomonic signs, but the passage of leukoplakic membrane must be watched for. Leukoplakia of the bladder does not respond to irrigations or instillations and resection; electrodesiccation, radium and nephrectomy must be relied on.

*Cysts.*—Rovsing<sup>20</sup> states that nephrectomy for polycystic kidney is attended by a high mortality. Milkaniewskis in 127 cases of nephrectomy reports a mortality rate of 30 per cent. Death was frequently due to such complications as tuberculosis, calculous pyonephrosis or malignant disease. Rovsing advises exposing the kidneys and puncturing the

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18. Von Borza, Jenö: Ueber die Leukoplakie in den Harnwegen mit Bemerkungen über die Ätiologie des Krebses, *Ztschr. f. urol. Chir.* 19:194-200, 1926.

19. Briggs, W. T., and Maxwell, E. S.: Leukoplakia of the Urinary Tract with Reports of One Vesical and Two Renal Cases, *J. Urol.* 16:1-22 (July) 1926.

20. Rovsing, Thorkild: Die Behandlung der multilokulären Nierenzysten nebst Bemerkungen über die Art Dieses Leidens, *Deutsch. med. Wchnschr.* 1:614-615 (April 9) 1926.

**Consistency.**—The tumor was noted as soft or cystic in twenty-nine cases, tense in two, encapsulated in five, and as firm, nodular or shotty in thirty-two. The term "indurated" was used for seven, and "hard" or "hard, like cancer" for two.

**Mobility.**—In forty-two cases the growth was movable; it was fixed in only one (case 4), and in that a marked infection was present.

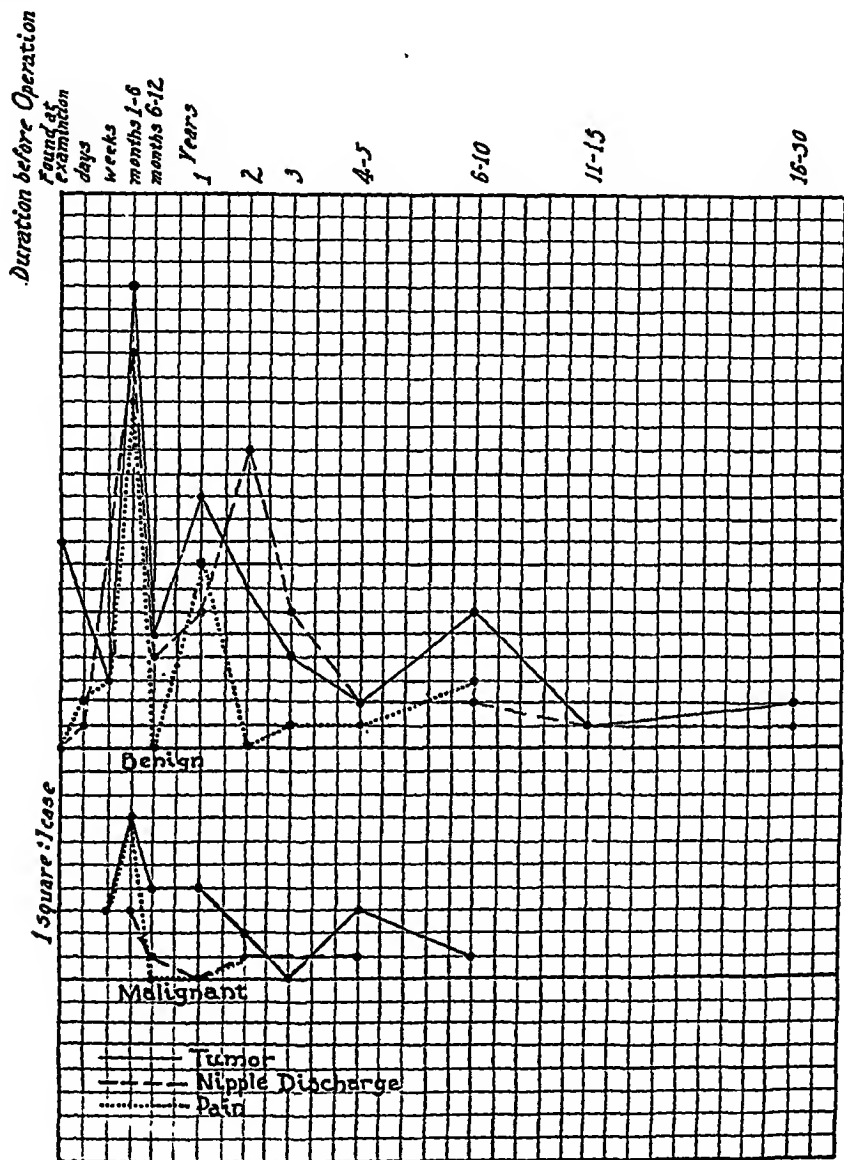


Fig. 4.—Duration of the growth of the tumor, nipple discharge and pain with the number of cases for each period. It will be noted that these run a somewhat parallel course, except that the number of cases with pain decreases more rapidly for the periods of longer duration, and that nipple discharge is much less prominent in the cancer than in the benign group.

**Nipple.**—In forty-three cases the nipple was noted as normal; in twelve, there was slight retraction; in three, it was protruded, and in

rence of the stones after repeated removal, frequent attacks of anuria with high retention of blood nitrogen, the extensive destruction of renal tissue without corresponding functional impairment, and the patient's ability to carry on active practice as a physician in spite of almost total absence of functioning renal tissue. Microscopic examination of the right kidney obtained at necropsy showed extensive parenchymal destruction with replacement by fibrosis and other inflammatory elements; practically no functioning renal tissue could be seen.

*Hematuria.*—Gottlieb<sup>23</sup> reviews the various theories of so-called essential hematuria. Senator advanced the hypothesis of isolated renal hemophilia to explain the process. Israel found in his cases nodes of interstitial nephritis. Klemperer found the condition associated in one of his cases with hysteria and neurasthenia, and advanced the hypothesis that angioneurosis, whereby the blood vessels became widened, allowing diapedesis of the red cells, was the cause of the disease. Golling, in 1909, described nephrosis in thirty-five of forty-seven cases. Wessel, in 1923, described forty-three surgically treated cases. In thirty-four of these he could demonstrate organic conditions such as paranephritic changes, varicose widening of a renal papilla, small aneurysms in the cortex, pyelitis and papilloma of the renal pelvis. In nine cases no pathologic change was found.

Congenital vascular anomalies, nodose glomerulonephritis (Kretschmer) and what Scheele and Klose call "bleeding from a node" are other explanations of the disease.

Two cases are reported by Gottlieb, one in which the kidney removed at operation showed an increase of the connective tissue around the papillae with metachromasia of the cellular elements and widening of the associated collecting tubules. A diagnosis of papillitis renis fibrosa was made. The other case showed no urologic anomaly or pathologic change on close investigation, except the presence of erythrocytes in abundance in the urine. Blood clots were never found. The diagnosis of essential hematuria was made by exclusion. The patient remained unimproved by treatment. Gottlieb considered the bleeding to come from a small node without demonstrable pathologic cause. After a month, 2 per cent silver nitrate solution was instilled into the renal pelvis. This caused some reaction accompanied for four days by increased bleeding and then cessation of hematuria.

In discussing the treatment, Gottlieb expresses the opinion that conservative treatment with instillations of silver nitrate is suited to the

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22. Hinman, Frank; and Gibson, T. E.: Report of a Remarkable Case of Recurrent Urinary Lithiasis in a Physician in Active Practice, with an Unbelievably Small Amount of Renal Tissue; Death, Not from Uremia, but Due to Cardiac Failure, *J. Urol.* **16**:43-58 (July) 1926.

23. Gottlieb, J.: Ueber die sogenannte essentielle Hämaturia, *Ztschr. f. urol. Chir.* **18**:237-247, 1925.

*Lymph Glands.*—In sixty-four cases the lymph glands were negative; in nine palpable, and in only one case (case 4, infected) were they hard and suggestive of malignancy.

*Pathologic Examination.*—The specimens and histories as received in the laboratory show that in 22 per cent the tumor only was removed; in 40 per cent the breast without the axillary contents or pectoral muscles; and in 38 per cent the radical operation for cancer was performed. In many cases (more than 50 per cent) in the last two groups exploratory incisions had been made.

The tumors were noted as single in 63 per cent of the cases, and multiple in 37 per cent. The size has already been given fairly accurately under the physical examination.

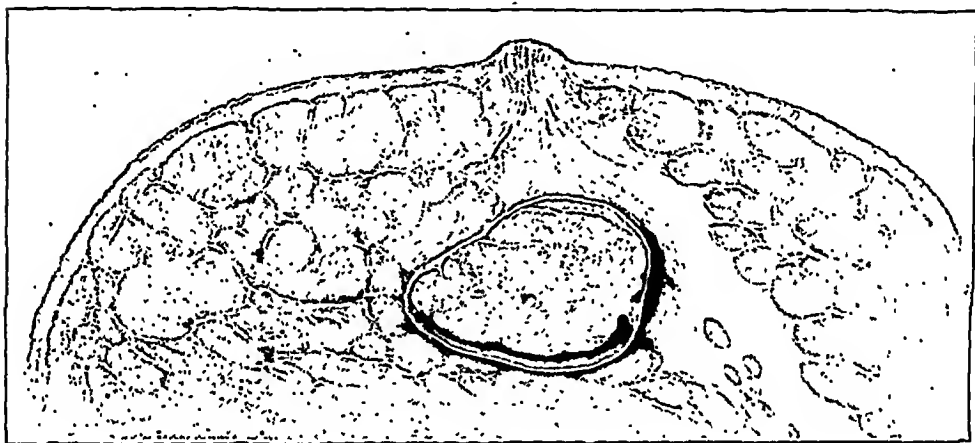


Fig. 6.—Ultimate results in the benign and malignant groups: among sixty-six cases of the benign group, followed for from one to twenty-two years, there were no deaths from tumor or recurrence, and relatively few deaths from any cause; in the malignant group, on the other hand, can be seen the high mortality from recurrence, only three patients being alive at the present time.

Section through the tumor showed a cyst, which was filled with a papillomatous mass in 3 per cent of the cases; in the remainder it contained fluid and one or more papillomas (fig. 6). The fluid was bloody in 83 per cent of the cases noted; in 11 per cent it was clear, and in one case each the cyst was filled with green pus, grumous material and cloudy fluid. Of the twenty-nine cases with no note on the cyst fluid, the nipple discharge was bloody in eight cases, watery in two, and green and yellow in one each; the type was not noted in three; in seven there was no discharge, and in seven there was no note. In three of the other ten cases in which the fluid was clear or amber, there was a history of a bloody discharge at some time; in three, a yellow or serous discharge; in three others, no discharge, and in one there was no note.

## INTRACYSTIC PAPILLOMATOUS TUMORS OF THE BREAST. BENIGN AND MALIGNANT

ANALYSIS OF ONE HUNDRED AND TWENTY-FOUR CASES \*

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This breast tumor may now be considered as a distinct type made up of a cyst or dilated duct into which projects a soft, friable, papillomatous growth. In occasional cases in the same breast, or in the wall of the cyst, definite carcinoma is present with invasive and metastatic properties. In the literature the condition is referred to under various names—adenoma, villous papilloma, duct papilloma, cystadenoma papillae, polycystoma proliferum, proliferating cystadenoma, papillary cystoma, duct cancer and carcinome villex. With these is often described another tumor of common occurrence, but one that only rarely takes a form that could be confused with the true papilloma. This growth shows a cauliflower-like projection into the cyst, rather than the soft, friable, delicate branchings of the primarily epithelial structure. It is referred to as cystadenoma intracanalicular, intracanalicular cystadenoma or myxoma, and endocanalicular papillary fibroma. We have been accustomed to call this the intracanalicular fibro-adenoma or myxoma, and it seems to be primarily and predominantly a connective tissue growth. Two cases of this type of tumor are included in this series, for the reason that clinically and at operation they present a similar picture.

The result of this study, based on 104 benign and twenty-four malignant tumors and five cases with the diagnosis uncertain may serve (1) to emphasize the number of cases wrongly diagnosed as cancer; (2) to bring out the points of differential diagnosis between the benign and malignant forms, both clinically and at the exploratory operation, and (3) to present a method of attack that will give the patient the best chance of a correct diagnosis and proper treatment.

Furthermore, since the largest series of similar tumors heretofore reported has included about twenty cases, Deaver and McFarland basing their chapter in *The Breast* on forty compiled cases, and the literature being made up largely of small groups of individual reports, it is hoped that the study of this series will make a definite addition to the information available on this type of breast tumor.

\* From the Surgical Department of the Johns Hopkins Hospital and University.



adenoma or myxoma (fig. 17 and cases 10 and one case not reported here).

The wall of the cyst was not infiltrated in fifty cases; it was thick in two, but in no case is infiltration recorded (fig. 6). In most cases it is stated that the wall was thin, freely movable over the surrounding tissue, and with no attachment to, or infiltration of, the adjacent structures.

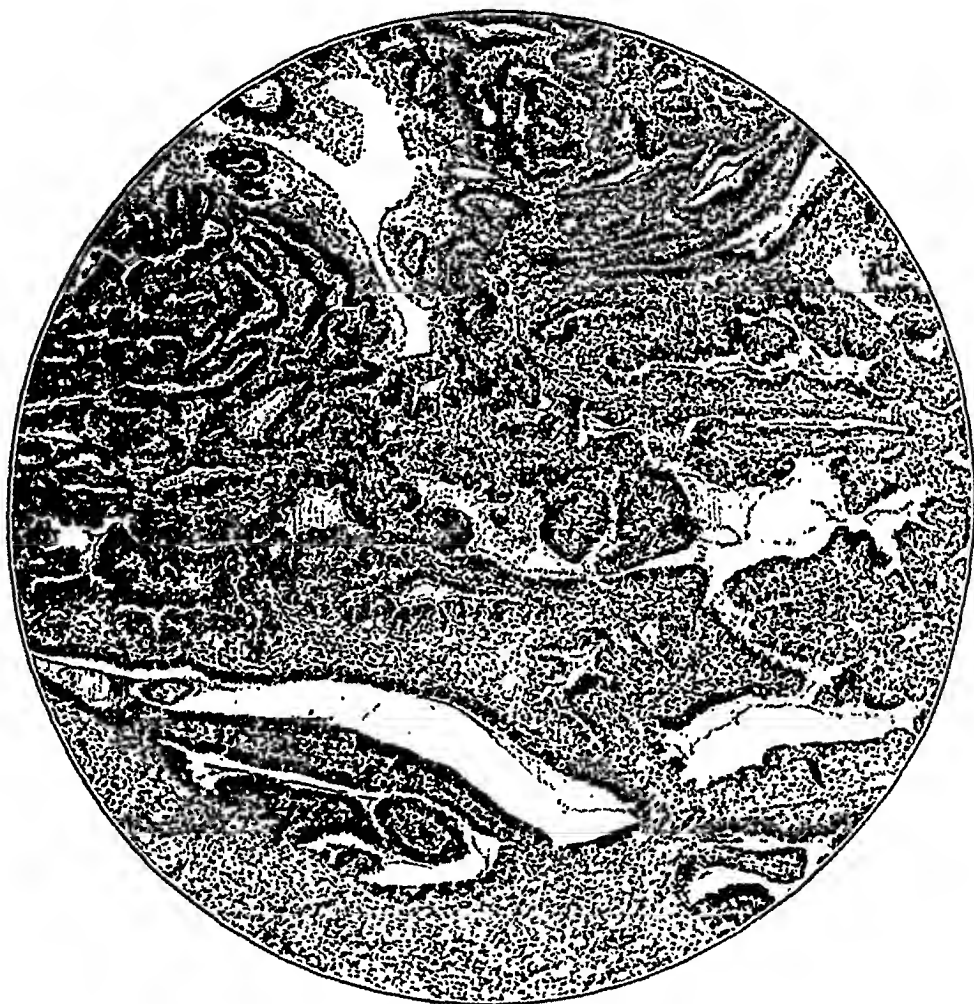


Fig. 8.—Benign papillomatous cyst, showing the pedicle of the papilloma, with the fibrous tissue stroma and the covering of duct epithelium. The intracystic growth has in places the true papillomatous form, while in other areas there is a glandlike arrangement, the latter possibly due to a fusion of the papillae. In the tumor growth and in the surrounding tissue there is marked cellular infiltration and large quantities of blood pigment.

Microscopically the smooth wall of the cyst was lined with duct epithelium, occasionally flattened out, but usually columnar. Sections through the base of the papilloma showed the fibrous tissue framework, which contained the blood vessels, growing up from the connective tissue

tases were found. Warren<sup>9</sup> gives a good prognosis after early and complete removal, stating that in recent cases removal of the breast or even of the tumor alone is all that is called for, but that without this the danger of malignant sequelae is very great.

Speese<sup>10</sup> cites two cases which from his report seem to be unquestionably benign. In one a radical operation was done on a girl of 22 years who had had a tumor for eight years. The other patient, aged 35, had only the tumor removed, this showing a cyst with a smooth wall except for one small, red, papillary projection. She refused to have a radical operation and was well eighteen months later. He doubts the diagnosis of malignancy in these two cases.

Our early records are in accord with the prevailing opinion expressed in the literature concerning the nature of these tumors. In the histories of cases now diagnosed as benign there are repeated pathologic reports of malignancy, but with a good prognosis "since this type of cancer metastasizes relatively late." The later records likewise impress on us the present day, widespread persistency of fear of malignancy in these tumors: many of the specimens that were received with a provisional diagnosis of cancer have, after a careful study, been placed in the benign group. Three recent striking examples of this may be cited. In the first a girl of 16 had both breasts removed because of a bloody nipple discharge and a microscopic diagnosis of cancer. In the second, a girl of 22, with a history of a tumor of two years' duration, clinically benign, had the entire breast removed after the tumor had been excised and found to contain bloody fluid. In the third case a diagnosis of "cancer cyst" was made, despite the fact that the tumor, as described by the surgeon, was encapsulated.

#### ANALYSIS OF CASES INCLUDED IN THIS REPORT

*Method of Investigation.*—At the beginning of this study each case was carefully worked over pathologically, grossly when the material was available, and microscopically in every case. Where there was a question of changing the diagnosis, the correctness of this revision was made more certain by including in this restudy the sections on which the original classification had been made. These cases were then referred to Drs. Bloodgood and MacCallum, and no changes were made without their joint approval. No mistaken diagnoses were found in the benign group, but ten cases, in addition to quite a number already reclassified as benign, had to be removed from the malignant group. Four of these were classed as unquestionably benign (under report of cases). Five

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9. Warren, J. C.: The Surgeon and the Pathologist, J. A. M. A. **45**:149 (July 15) 1905.

10. Speese, J.: Ann. Surg. **51**:212, 1910.

be seen varying degrees of round or polymorphonuclear cell infiltration (figs. 7 and 11). Also, quite frequently the tissues were deeply stained from old hemorrhage, with enormous numbers of phagocytic cells loaded down with blood pigment (fig. 12). Associated with the foregoing conditions was every grade of fibrous tissue proliferation (figs. 12 and 13).



Fig. 10.—Section taken from a breast the seat of benign papillomatous cysts, showing a duct filled with epithelial cells and with the outline quite indefinite at places. About this duct are epithelial elements which are numerous for a breast that has never lactated, and all of these are located in an area of chronic inflammatory reaction and fibrous tissue proliferation. Areas like this, particularly in the frozen section, are often difficult to differentiate from cancer. This patient has remained well for five years since operation, at which time this type of tissue was cut through in removing the papillomatous cyst.

The multiplicity of these small areas and the distortion due to the hemorrhage and inflammatory reaction, together with their close relation to the wall of the large cyst, suggested occasionally that invasion

*History.*—In general these tumors occurred in women of any age after puberty, but most frequently between 20 and 65, with 4 per cent under 20 (fig. 1). The complaint was of a lump in the breast in seventy-five cases and a discharge from the nipple in sixty-nine cases, the two conditions being frequently associated. In twenty cases there was a history of the discharge alone; in ten of these patients a tumor was present on examination and the remainder had the operation performed solely for the bloody discharge. In eighteen patients with a complaint of a lump in the breast there was no history of a nipple discharge.

*Type of Discharge.*—The discharge was bloody in forty one cases, serous in eight, and varying between bloody and serous in seven. In one it consisted of green pus. In several cases there is no note as to its character. It was usually intermittent, sometimes with a complete cessation for a considerable time, while in other cases it occurred daily, and in a few it was present almost constantly. There were a striking number of reports in which it was noted only, or was more marked, at night, this condition probably being due to the position of the patient causing pressure on the breasts. The usual story was that of a gradual growth, but a few patients had noted a rapid increase in size, associated with pain, and either a cessation of the discharge or tenderness, redness and evidence of infection. Four of the tumors had ruptured with a discharge of a bloody material, in one case on three occasions, and three of the patients came in with a persisting sinus and a purulent discharge. (Greenough and Simmons report a case with a sinus.)

*Cessation of Discharge.*—There are sufficient data to establish the fact that in these tumors with a cessation of the discharge there is frequently an increase in the size of the tumor. It becomes more tense and painful, and the pain is relieved by the reappearance of the nipple discharge, the tumor at the same time decreasing in size and becoming softer in consistency. There was a definite history of seven tumors decreasing in size, five disappearing entirely for a variable period of time, in two with a known associated discharge of material from the nipple.

*Onset.*—The first thing noted was the discharge from the nipple in forty-seven cases, a tumor in thirty-seven, and pain in thirteen. The pain in five instances caused the patient to discover the tumor.

*Duration of Symptoms.*—The duration varied for the decades since our first recorded cases as follows: Those since 1920 had an average duration of 1.76 years, increasing with each decade back to the earliest cases between 1895 and 1900 when the average duration was 4.75 years (fig. 2). The total number of patients falling in any period of duration from a few days to twenty-five years can be seen at a glance in fig. 3. Eighteen of the patients had had symptoms for five years or more. The

record of a case which showed this picture alone and in which there was a recurrence, regardless of the type of operation performed.

The lymph glands were negative in the thirty-four cases noted, there being no record of involvement in any one of this series.

As to infection, every grade of inflammatory reaction has been encountered from a slight cellular infiltration to a cyst filled with cloudy

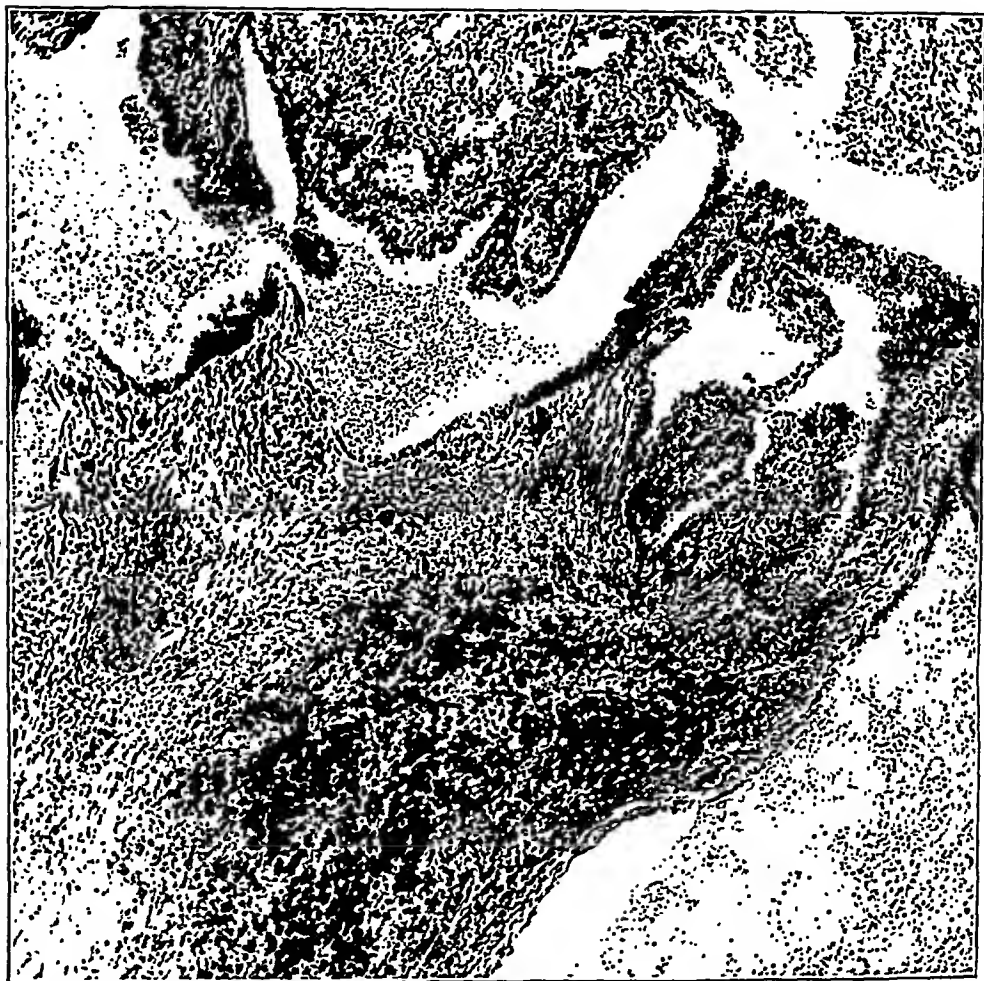


Fig. 12.—Papillomas arising from a duct within the nipple: on one side is the stratified squamous epithelium, with the sharp line of demarcation between it and the duct epithelium; the former is in close apposition to the papillomatous growth; there is marked inflammatory reaction as evidence of infection.

or purulent material, the papilloma having been largely destroyed and the surrounding breast riddled with minute abscesses. In the cases with the more severe grades of infection only a small, cellular, friable thickening of the wall had persisted to denote the location of the papilloma, and grossly this has often been called cancer. The misinterpretation seems to have been due to the adherence of the surrounding tissues, and the

majority of which were small, but with 38 per cent of those with the size noted being as large as an egg, base-ball, orange, grape-fruit, or more than 6 cm. in diameter. In an occasional case there were similar tumors in both breasts, and 15 per cent of these patients, either at the first examination or later, showed a similar condition in the other breast.

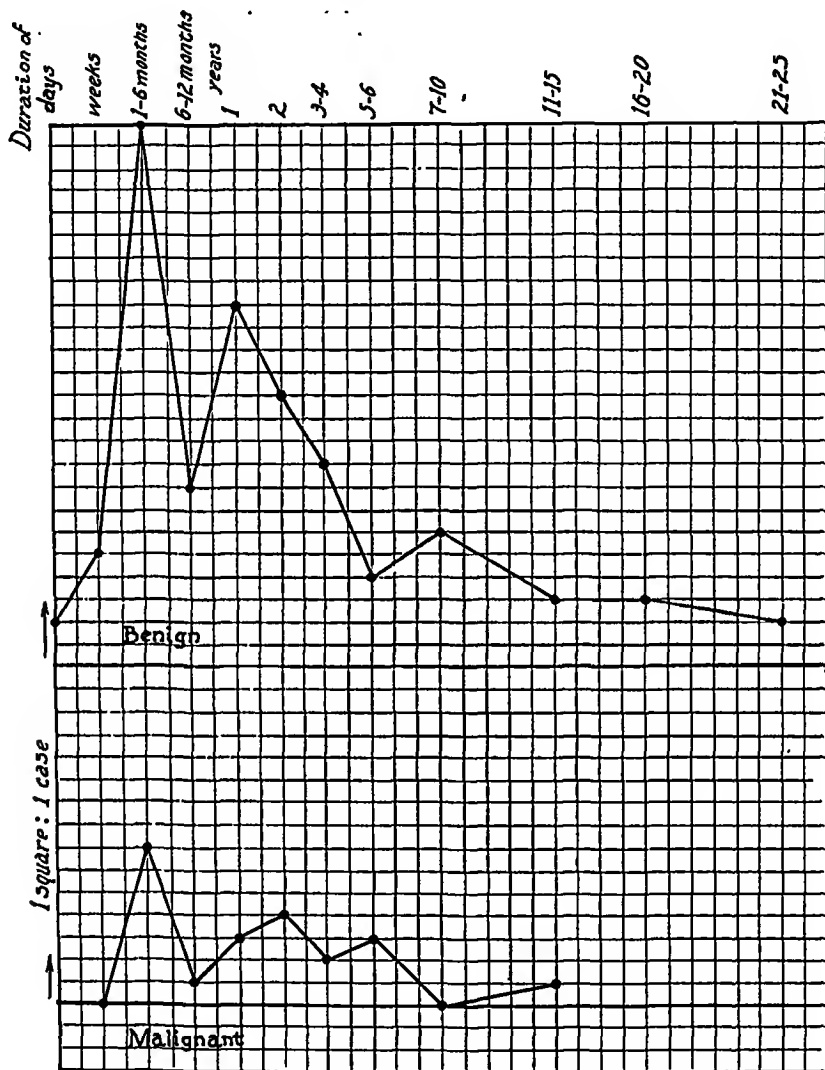


Fig. 3.—Duration of cases before operation: the relatively large number of benign cases of many years' duration, and with only one cancer case present over so long a period of time as to suggest that there has been malignant change in an old benign tumor, should be noted.

*Location.*—As a rule the tumor is in the central part of the breast, thirty-seven of the forty single or small tumors, with the location noted, being in this situation (fig. 5). In eight other cases it occupied the greater part of the breast, or there were multiple growths through the gland. In forty-eight cases the site was located by quadrants and not with reference to nipple or periphery.

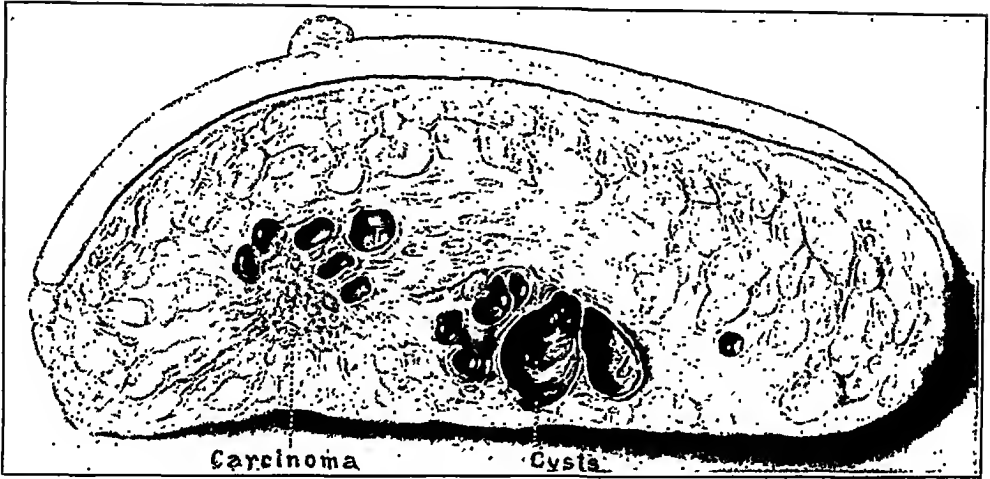


Fig. 14.—Area which on gross examination was thought to be scirrhus carcinoma: there is a dense fibrous tissue formation and embedded within it are certain more or less normal epithelial structures; on one edge is a small tag of a papilloma. This picture, particularly in frozen sections, is easily confused with scirrhus carcinoma, and suggests an invasion of the structures about the cyst.



Fig. 15.—Scirrhus carcinoma in a breast the seat of multiple papillomatous cysts: the definite walls to the benign cysts as contrasted with the invasive nature of the malignant growth should be noted.

two obliterated. Here again these last two cases showed marked infection (case not reported here and case 4).

*Skin.*—The skin was normal in fifty cases, showed a sinus from rupture in three, was tense, thin or red over the tumor in five, and had dilated veins in one. There were slight changes, either dimpling, fixation or

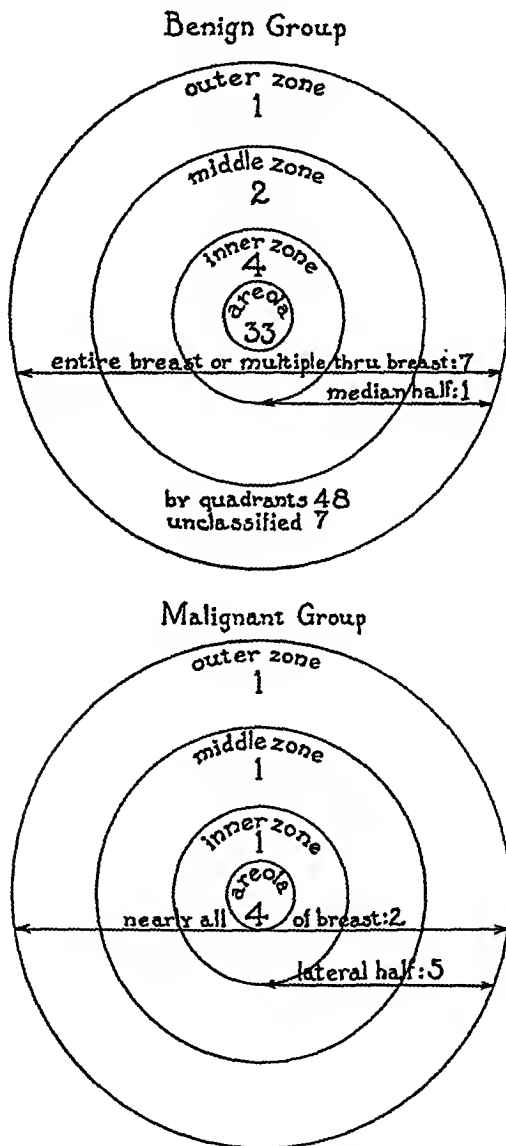


Fig. 5.—Location of breast tumors: where noted, these are predominantly tumors of the central part of the breast, but occasionally in the benign group they are multiple throughout the gland; in the malignant cases they are more frequently large enough to involve the greater part of the breast.

suggestive pig-skin appearance in nine, definite dimpling in two cases. In one of these infection was apparent, but with the section which we have of the other no diagnosis as to infection can be made. No history is given.



present less than six years. This last patient gave a history of a slow growth over a period of eleven years. The mass was then incised, only bloody fluid being obtained, after which the classical picture of malignancy rapidly developed. Evidently the tumor had been benign for a considerable time. This patient on clinical examination, thirteen years after onset and two years after the incision, had unquestionably a carcinoma, and the radical amputation was performed. She returned

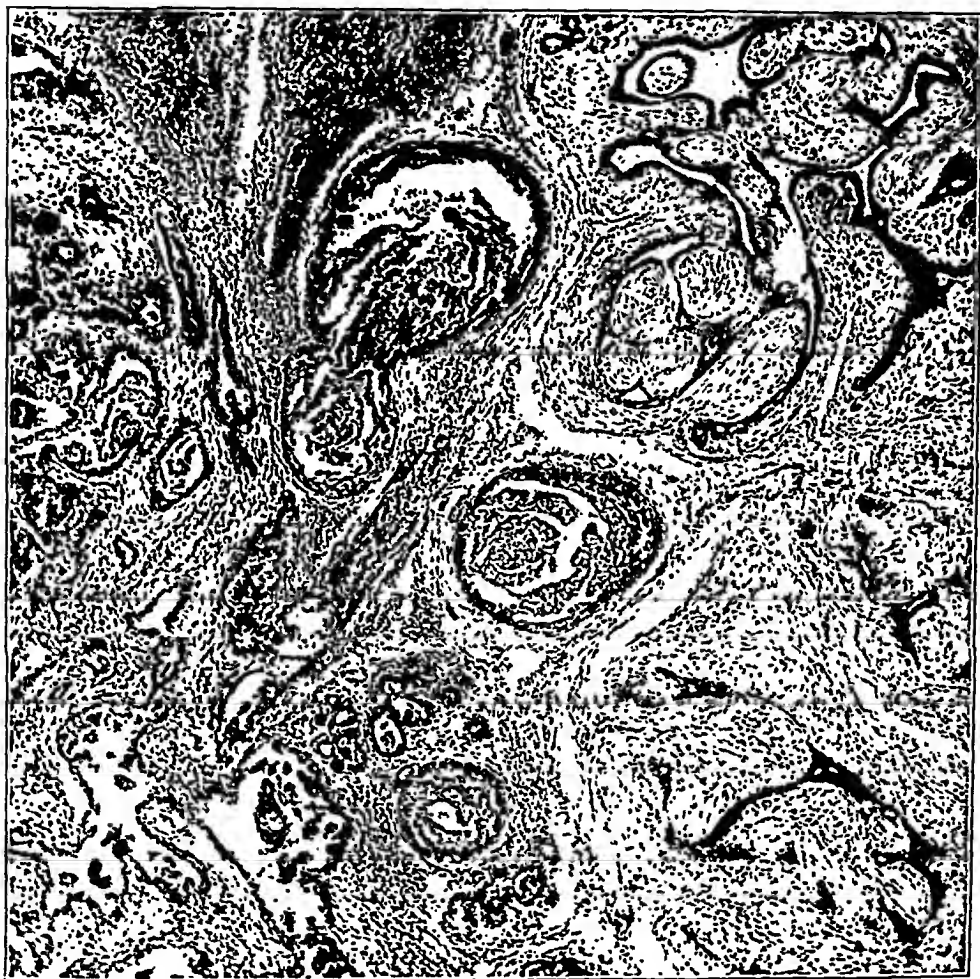


Fig. 17.—Section of breast with extensive carcinoma, which is lying in close approximation to benign, intracystic papillomas.

two years after operation with an ulcerated, local recurrence and this within a year caused her death. Figure 2 shows that in the cancer group there has been a gradual increase in the average duration of the growth for each decade since 1890. This is contrary to what would be expected in view of the extensive, recent educational propaganda. On closer study, however, it is seen that this rise is dependent on two cases (six and thirteen years' duration), one in each of the last two decades, and that

After the fluid had been evacuated the cysts were found to contain amounts of papillomatous growth varying from a small mulberry-like projection at one point in a large, smooth-walled cavity, to a cyst with a shaggy wall due to numerous, small papillomas, which occasionally completely filled the cyst. Ten patients were operated on for a bloody nipple discharge alone, and showed, either on gross or microscopic examination, a small papilloma projecting into a dilated duct.



Fig. 7.—Benign papillomatous cyst with the papilloma almost filling the cyst and appearing as a solid growth. There are few points of attachment; the thickening of the wall at one place is due to the closely attached papillomatous growth. The entire freedom of invasion, the loose attachment of the wall to the surrounding tissue, and the location beneath the nipple should be noted.

In a few cases, two of which are included in this series, there was a cauliflower-like growth projecting into the cyst. This clinically and at exploratory incision is often confused with the predominantly epithelial type of tumor. On microscopic examination, however, it showed the large projections to be the typical intracanalicular fibro-

## DOUBTFUL GROUP: BENIGN OR MALIGNANT

A composite picture of this group is not given, since their character is a matter of uncertainty, and accordingly each case is given in detail under the report of cases. In reading over the records, I find nothing in any of the histories or examinations which could not well go with the benign group. Even the pathologic reports of "medullary carcinoma," "adenocarcinoma" and "typical adenocarcinoma of the papillary type" can be duplicated several times in the early diagnoses of cases now thought to be unquestionably benign. The case diagnosed as cancer without microscopic confirmation must unquestionably be placed as doubtful.

My own feeling is that all of these cases were benign, and were they added to the benign group they would cause little change in that composite picture other than an increase in the number of patients submitted to radical treatment, as well as in the number cured.

Two patients are dead, one after three and one-half and the other after eight years, of causes other than cancer. Three patients are living and free from recurrence, two, four and thirteen years after operation. The removal of these, together with the many benign cases, from the malignant group, has so reduced the number of cases of cured cancer that in the remainder a poor prognosis must be given instead of the usual encouraging report based on their "relatively low grade of malignancy."

## ULTIMATE RESULTS

*Benign Group.*—Of the sixty-six out of ninety-five patients in this group who could be followed, not one showed any evidence of recurrence. Nine are dead: one after one year, by suicide; one, after one year, of carcinoma of the cervix; one after two years, in an automobile accident; one after three years, of pulmonary tuberculosis; one after seven and one after eight years, both probably of cerebral hemorrhage. In addition, three who did not have any recurrence are said to be dead.

*Malignant Group.*—1. Of the ten patients in this group who showed metastases to the glands, one has recently died of recurrence three years after operation; six died of recurrence and metastases within five years: one died of some unknown cause one year after operation; two died of "pneumonia" and "heart trouble" after ten and twelve years, respectively.

2. Of the nine patients without lymph gland metastases: for one there is no note; one died of streptococcal wound infection on the second day after operation; two died of metastases within one year after operation: one died of medullary carcinoma of the other breast (noted above with question as to malignancy) after seven years; one died after four years, without recurrence (morphine addict); one died of pneumonia, after six years, having had no recurrence; one died of some unknown cause six years after, and one is well seven years after operation.

about the cyst, and over this a covering of from one to several layers of epithelial cells, but usually a single layer of columnar epithelium (fig. 7). Often one could see clearly the delicately branching papilloma with the connective tissue covered with epithelium (fig. 8), while another common picture was a glandlike arrangement, with spaces lined with epithelium lying in the connective tissue (figs. 7 and 8). In still other areas the surface of the papilloma was covered with several layers of

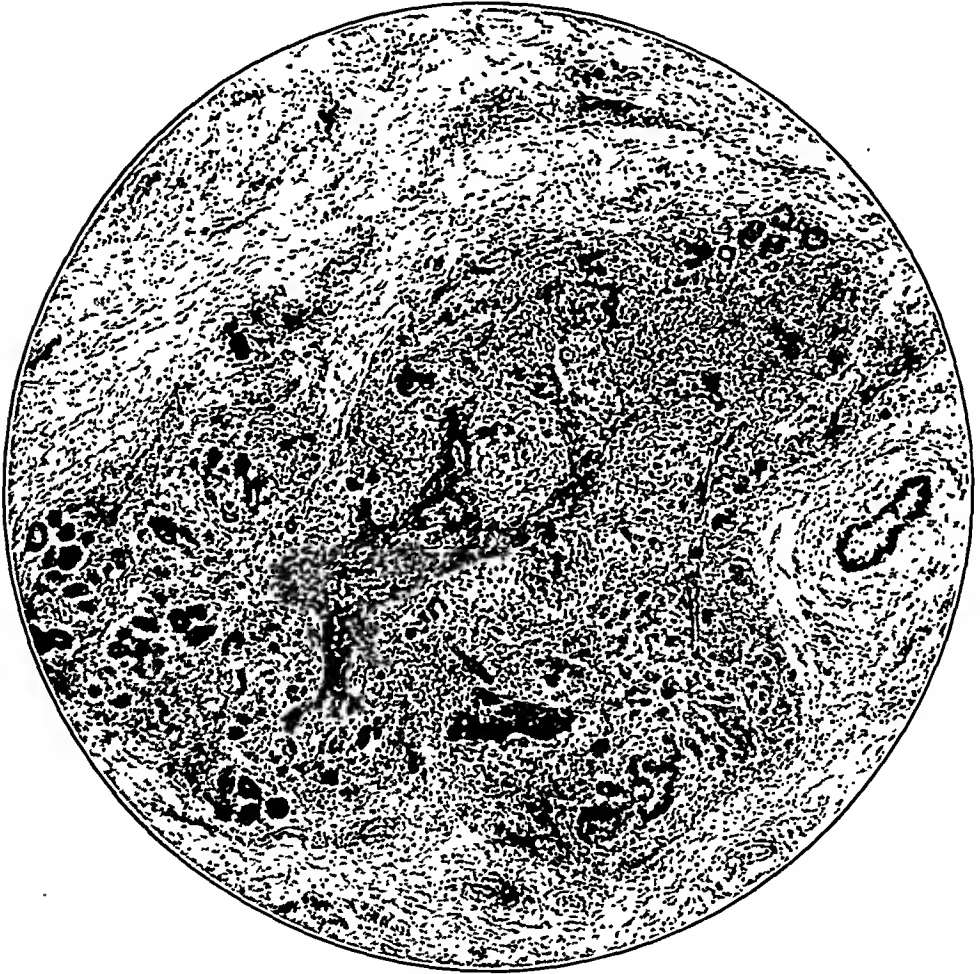


Fig. 9.—Higher magnification of a papillomatous growth, with some hemorrhage between the papillae. There are many points of attachment of the growth, and at times it is difficult to follow the rather indefinite wall. Frequently, with the microscope one may become lost within this maze of growth, whereas with the dissecting lens or on gross examination a definite wall can be seen.

epithelial cells, or with these growing to form solid masses almost free from connective tissue. About the cysts were noted various grades and kinds of epithelial proliferation or inflammatory reaction, small cysts with papillomas, solid duct adenomas (fig. 9), nonencapsulated adenomatous areas (fig. 10), cystic adenomas, or dilated ducts. Around these could

## Summary of Cases

History	Benign (95 + 9 bilateral operations = 104 cases)		Malignant (24 cases)	
	Number	Per Cent	Number	Per Cent
<b>Clinical Diagnosis:</b>				
Benign.....	61	64	1	4
Malignant (clinical or exploratory).....	34	36	21	95
<b>Symptom of Onset:</b>				
Nipple discharge.....	47	48	3	12.5
Tumor.....	37	38	19	79
Pain.....	13	13	2	8
<b>Summation of Symptoms (104 cases benign; 24 malignant)</b>				
Nipple discharge.....	69	66	8	33
Tumor.....	85	81	24	100
Pain.....	43	41	16	67
<b>Clinical Examination:</b>				
Number single.....	62	83	18	85
Number multiple.....	13	17	3	15
<b>Size:</b>				
1 to 2 cm. ....	25	43	2	10
3 to 5 cm. ....	11	19	4	20
6 cm. +.....	22	38	14	70
<b>Consistency:</b>				
Soft, fluctuating, cystic.....	29	37	3	15
Tense.....	2	2.5	1	5
Encapsulated, circumscribed.....	5	6	..	..
Firm, nodular, shotty.....	33	42	..	..
Indurated.....	7	9	..	..
Hard, hard like cancer.....	2	2	16	80
<b>Nipple:</b>				
Normal.....	43	65	8	40
Slightly retracted.....	12	18	0	..
Protruded.....	3	5	0	..
Retracted.....	8	13	12	60
<b>Skin:</b>				
Normal.....	49	71	4	17
Tense, red, ulcerated, sinus.....	9	13	4	17
Slight change.....	9	13	0	..
Dimpled.....	2	3	3	12
Infiltrated; attached; pig-skin; metastases	0	..	15	62
Dilated veins.....	0	..	2	8
<b>Mobility:</b>				
Movable.....	42	68	6	54
Attached.....	1	2	5	45
<b>Lymph Glands:</b>				
Negative.....	64	86	5	25
Palpable.....	9	12	5	25
Hard, suggestive of cancer.....	1	1	10	50
<b>Operation:</b>				
Tumor.....	22	22	0	..
Breast.....	41	40	1	4
Complete for cancer.....	33	38	23	96
<b>Pathologic Examination:</b>				
Number single.....	51	63	20	91
Number multiple.....	30	37	2	9
<b>Character:</b>				
Cyst with papilloma.....	59	100	2	9
Cyst with papilloma and thick area in wall.....	0	..	4	18
Cyst with invasion or cancer in wall...	0	..	16	73
<b>Cyst Wall:</b>				
Not infiltrated.....	50	96	1	7
Thick.....	2	4	1	7
Infiltrated.....	0	..	13	87
<b>Cyst Fluid:</b>				
Bloody.....	60	83	9	82
Clear.....	8	11	0	..
Other type.....	4	6	2	18
<b>Lymph Glands:</b>				
No glands removed.....	57	63	0	..
Negative.....	34	37	9	45
Metastases.....	0	..	11	55
<b>Ultimate Result:</b>				
Number of cases followed (95 benign and 24 malignant).....	65	70	22	92
Living and well, 1 to 22 years.....	57	57	3	13
Dead, no recurrence, 1 to 14 years.....	9	13	4	18
Dead, cause unknown, 1 to 13 years.....	0	..	3	13
Dead from cancer, 1 to 7 years.....	0	..	12	55

had taken place. Even microscopically at times the outline was not absolutely definite (figs. 8, 9 and 13).

A still more confusing picture was seen in a small percentage of cases that showed an area of hard, fibrous tissue, which grossly resembled scirrhus carcinoma, and which, microscopically, was found to be made up of dense, connective tissue or scar, scattered through which were

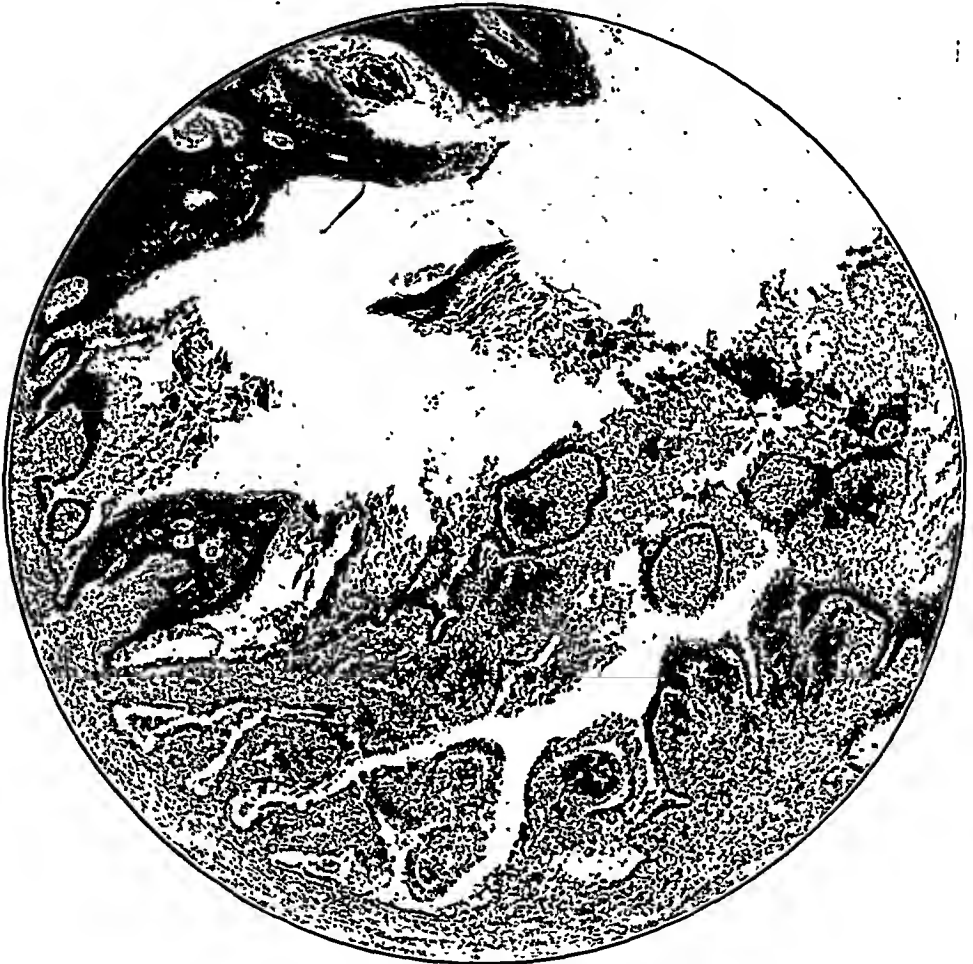


Fig. 11.—Extensive epithelial hyperplasia in a breast that had never lactated from the same patient as figure 9. This tissue was cut through at operation, and there was no subsequent tumor formation.

clumps of epithelial cells (fig. 13). On superficial inspection this had a structure similar to that of scirrhus carcinoma. However, on more careful examination the individual cells did not appear malignant, but were of uniform size, outline and staining reaction. No mitotic figures could be seen, and individually the cells suggested a benign, epithelial growth, probably breast acini and ducts that had been trapped or included in the scar tissue proliferation. So far as can be determined, we have no

We will dismiss as having received proper treatment this group of clinically malignant cases in which no mistaken diagnoses have been found, except for the occasional infected cyst that has been called cancer. There remain that larger number of cases that we consider to be clinically benign. In these there were frequently slight changes in the nipple, skin or lymph glands which were suggestive of malignancy, or the tumor itself was unusually firm or irregular for a benign lesion. These conditions are considered below, and explanations as to their causation are offered which, if accepted, make it evident that such slight changes have to be discounted in this type of tumor. A careful analysis of the mistaken diagnoses in this series shows that the clinical impression of malignancy has been founded on the bloody discharge and on the slight changes in the skin, nipple and axillary glands, together with the consistency of the tumor. Or, more frequently, the deciding factor has been the gross or microscopic examination at the time of exploration. Surgeons have come to look on blood in a cyst as evidence of cancer, but the foregoing data seem sufficient to justify us in ignoring the cyst contents and in emphasizing the importance of a careful study of the attachment of the wall to the surrounding structures. We are justified in treating the tumor as benign if the wall is freely movable over the adjacent tissue and there is no evidence of invasion.

In addition to the explanations of these observations which are offered below, we shall compare or contrast the benign and malignant groups, as well as correlate the data obtained from this study with the reported cases, more particularly the larger series found in the literature.

*Age.*—Intracystic papillomatous tumors of the breast are usually considered to belong to middle or advanced age; Deaver and McFarland state that they usually occur in the breast of women who have passed the menopause, and give the average age in their cases as 46.6 years. In the cases reported by Warren the average age was 52; in those of Greenough and Simmons it was 49.5, while in the compiled cases of Williams it was 43. In this series the mean age was 42, with sixty of the cases in patients less than 45, while eight occurred in women less than 25 years of age (fig 1).

In the cancer group all our patients were more than 35 years of age. However, in the doubtful group there was one patient younger—only 27. This, together with the fact that cancer of the breast occurring before 25 years of age is a most unusual condition, would justify treating a definite number of these cases as benign, unless they are unquestionably malignant. Despite the age of the patients, however, in some the diagnosis of cancer has been made and they have been submitted to radical treatment. The most striking case occurred in a girl whose first trouble—a bloody discharge from the left nipple—came on at the age of 15.



extension of the inflammatory reaction into them, a condition quite evident in the microscopic sections. These are the cases which clinically gave the picture of cancer, and in which at exploratory incision it was impossible to rule out malignancy owing to the induration and fibrous tissue reaction which prevented an intelligent selection of areas for examination, since everything was suggestive. With this clinical picture the radical operation has been, and probably will continue to be, performed. The pathologist, however, with sufficient time to study many

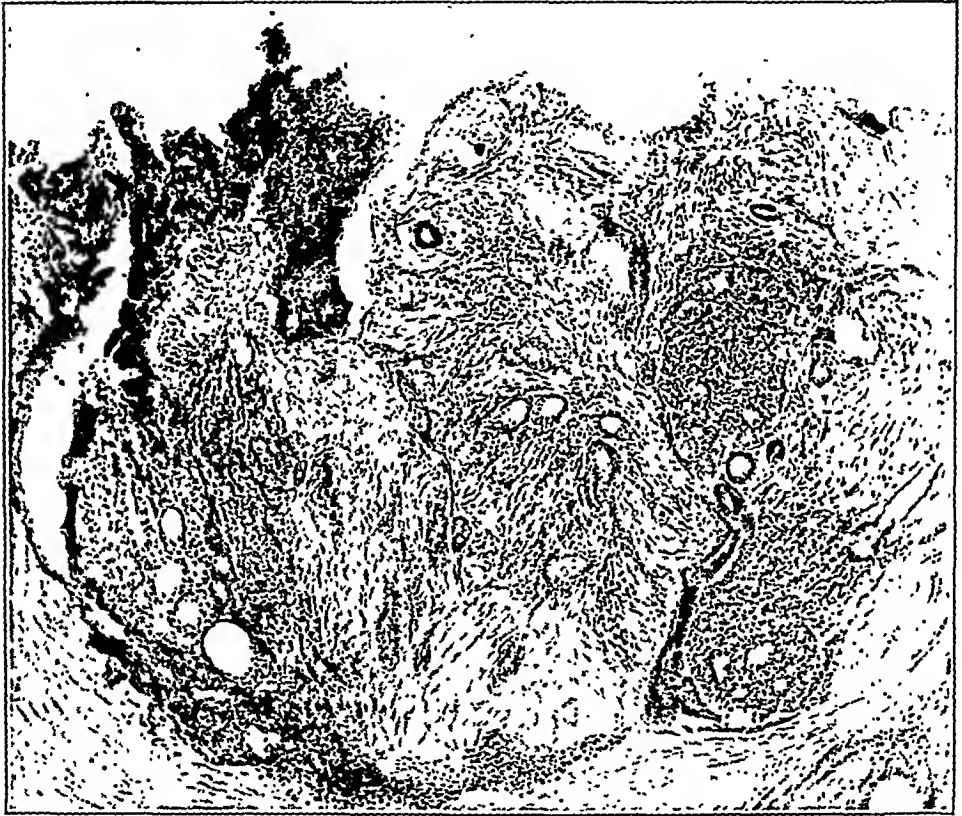


Fig. 13.—Hemorrhage into the cyst and adjacent tissue: about the cyst are numerous phagocytic cells filled with old blood pigment; they are located in a scar due to the marked proliferation of connective tissue cells.

sections can make a diagnosis of a benign tumor, so that the patient can be reassured as to the outlook.

#### MALIGNANT GROUP: COMPOSITE PICTURE

The study of this group is based on twenty-four cases.

The malignant cases have shown clinically, grossly and microscopically characteristic and well defined carcinomas (figs. 14, 15, 16 and 17). Of the twenty-four cases, twenty-one were diagnosed clinically as malignant, two as doubtful, and one as benign. The latter three



Ten of our patients were operated on for this alone and grossly or microscopically there were one or more small cysts with papillomas. Quite a few of this series have shown, after operation, a bloody discharge from the nipple of the same or opposite breast, but have had no further treatment, and none have developed cancer.

Bloodgood<sup>13</sup> in working up the significance of a bloody nipple discharge found cancer in about 1 per cent of cases. Furthermore, I think it will be generally conceded that the discharge in the majority of cases is dependent on the presence of a papillomatous cyst. This is one argument against the acceptance of a bloody discharge alone as indicative of malignancy. Other strong arguments are the observations in this group of cases, namely: (1) that 48 per cent of the benign and only 12 per cent of the cancer cases have a nipple discharge, which usually is bloody, as the symptom of onset; (2) that 66 per cent of the benign cases, as contrasted with 33 per cent of the cancer cases, at some time showed this nipple discharge; (3) no case of cancer showed nipple discharge unless tumor was palpable. A bloody nipple discharge, however, is held by Delbet and Mintz (cited by Ewing) as a sign of probable malignant degeneration.

One interesting section that recently came under our observation was from shreds given off with the bloody discharge, and showed the typical papillomatous arrangement. A diagnosis of a papillomatous cyst was made, but as it is not known whether or not this patient has had an operation since that time, the case is not included in this series.

*Pain.*—It is pain that brings the patient earliest for operation, this having a much shorter duration as a symptom than the tumor or nipple discharge (fig. 4). This is all the more striking when one considers that it is such a variable condition, frequently present only when there is a cessation of the discharge, and usually is not severe. It was present in one half of Greenough and Simmons' cases and in one third of the compiled cases of Deaver and McFarland, and was never severe. In other reports it is stated that pain is quite rare. In our cases there is a higher percentage of pain in the malignant group, in 67 per cent, as contrasted with 41 per cent in the benign group.

*Location.*—It can be assumed, as in the literature, that these tumors lie in dilated ducts, or that the cysts arise from dilation of the ducts, since a large percentage of them have direct connection with the surface through the duct opening at the nipple. Furthermore, in one of our cases and in one of those of Greenough and Simmons, a microscopic section shows the duct continuous from the cyst to the surface of the nipple. On microscopic study these cysts are frequently lined with columnar duct epithelium (fig. 7), so that it can be readily understood that they are predominantly tumors of the central part of the breast. In several

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13. Bloodgood, J. C.: Surg. Gynec. Obst. 3:721, 1906.

were diagnosed pathologically as cancer, and in the last, despite this diagnosis, the axillary dissection was not made until nine months later when the lymph glands were found replaced by a large, carcinomatous mass.

The age of onset in the malignant cases is shown in fig. 1 to lie between 35 and 71, but it should be noted that in one of the cases classed as suggestive of malignancy the patient was 27 years old. In



Fig. 16.—Medullary carcinoma located in a breast the seat of multiple small papillomatous cysts: the retracted nipple, thickened edematous skin, with a pig-skin appearance, the soft cellular growth, with invasive properties and the numerous, small, blood cysts should be noted.

the predominance of cases the age is between 40 and 60, with the mean at 51.

The symptoms of onset were a lump in nineteen cases, nipple discharge in three and pain in two.

From figs. 3 and 4 it can be seen that most of the cases were of less than three years' duration, and in all except one the tumor had been

tion. There was no suggestion of a tumor either in the right breast from which there had been recent bloody discharge, or in the left breast in which a tumor had been present for a few weeks in 1914, and had disappeared.

Oct. 8, 1924. The patient wrote as follows: "There has been a bloody discharge from the right nipple since the first of the year, but without a palpable tumor. On five or six occasions there has been a dull pain through the breast, but at these times I have realized that the discharge had been obstructed by a bit of cotton adhering to the opening. If I express the discharge it becomes bloody after the first few drops." She felt that there was no urgency at that time, since, if the cyst kept discharging, it would cause no harm except to her clothes, but that, in case the discharge should cease while there was inflammation in the ducts a cyst would form, and have to be cut out. She cited her previous experience as justification for this opinion.

With only the palpable tumor and the adjacent breast tissue removed, one must expect that similar tumors or a bloody discharge will develop in a certain number of cases. In our series, even with the entire breast removed in 78 per cent of the cases, 15 per cent of the patients had further tumors or nipple discharge on the same or opposite side.

This is contrary to Ewing's opinion that the tumors are usually single, occasionally multiple, and rarely bilateral. Deaver and McFarland also state that they are almost invariably single, but go on to describe them as irregular in outline and having a consistency varying in different areas. This we have found to be due to multiple, small, closely located tumors. Bowlby and Morton (cited by Deaver and McFarland) each give a case of recurrence. Greenough and Simmons have two cases recurring (six and eighteen months) after operation. It seems to us that these "recurrences" have more probably been the result of the growth of other small tumors which had been left behind. In the 15 per cent of our benign cases in which there was further trouble, the second tumor has not necessarily or usually been in the scar from the excision of the first tumor; frequently it has been in the opposite breast.

*Nipple Change.*—The changes in the nipple in the benign group—in the twelve cases with slight retraction and in some of the eight cases with more marked retraction—can be easily explained by the location of the tumor. The nipple changes have to be discounted with tumors located, as these are, beneath the areola, since the mechanical pressure on the ducts with the resultant displacement causes a tugging on the points of their attachment. Since they converge to the nipple where they are attached and this part of the breast is quite mobile, it is drawn in according to the amount of shortening caused by the displacement of the middle portion of the ducts. Furthermore, if the tumor involves the duct itself, this pull is the more easily understood. In a recent case with a single, superficial cyst, without a papillomatous tumor, in each breast near the nipple one could slide either of the freely movable tumors along beneath the skin and cause a complete inversion of the correspond-

if these are eliminated there is a gradual fall as is shown by the dotted line. The results of educating the public is better illustrated by the curve for the benign group. This consists of a much larger number of cases, and in consequence the data gained therefrom are more apt to be correct.

Nipple discharge was not such a frequent occurrence as with the benign group, occurring in only eight of the twenty-four cases, whereas a tumor was palpable in all (fig. 4).

In 60 per cent of the cases the tumor was 6 cm. or more in diameter, in the majority considerably larger, a condition which we would not expect to find at the present time.

In 65 per cent it was likewise noted as being hard, or "hard, like cancer." The nipple was retracted or showed fixation in fourteen out of the twenty cases noted. Skin changes were present in 75 per cent of the cases, and in 75 per cent there were enlarged axillary glands, two-thirds of which were clinically malignant on palpation.

*Pathologic Examination.*—This group showed predominantly single tumors, the majority having areas in the wall suggestive of cancer, with sixteen cases noted as "invaded" or with cancer in the wall, four as having thick walls, and with only one as not invaded. In this last case there were no metastases to the glands, and the gross description would suggest a benign tumor. It was described as a large cyst, with papillomatous projections, but with no invasion beyond the cyst wall. There was no local recurrence after radical removal, but five years later the patient came back with medullary carcinoma of the other breast, and with involvement of all the corresponding axillary glands. Her death was caused by metastatic carcinoma two years after the radical removal of this breast. From the sections which we have from this patient we have to call the first tumor cancer, though it is possible that these were taken from the intracystic growth, that the tumor of the other breast was a new development, and that this patient was cured of the first tumor. Of the cases with notes 55 per cent showed metastases to the axillary glands.

In all these cases except the one cited above, definite and well marked cancer with invasion was apparent (figs. 14, 15, 16 and 17), a picture that is not confusing in any way. A study of the sections shows that the cells very markedly in size, outline and staining reaction, that mitotic figures are abundant, and that the picture is that of typical cancer. It is entirely different from the pictures noted under the benign group, about which pathologists will disagree on a considerable number of cases. However, in these same breasts one very often sees some picture that was noted above under the group of benign papillomatous cysts, and these may, or may not, be in intimate association with the cancer (figs. 14, 15, 16 and 17).

group were diagnosed as having metastases into the adjacent lymph nodes, and on pathologic examination it was found that in 55 per cent of all cases the axillary glands were grossly and microscopically involved.

This high percentage of lymph gland involvement tends to strengthen our impression that many of the tumors heretofore reported as cancer are benign, since it is a strongly established opinion that the lymph nodes are involved only late in this type of so-called malignancy. Very few of the cases reported as cancer have shown it. Ewing states that the lymph nodes have a prolonged immunity. Bloodgood's report<sup>14</sup> in *Gynecology and Abdominal Surgery* by Kelly and Noble is based on eighteen benign and fourteen malignant cases. Five out of six of the latter patients remained well. Only one of these had lymph gland involvement, and in several of the cases the diagnosis has since been changed to benign.

*Infection.*—We find infection to be fairly common, but it is not mentioned in the literature of these cases so far as we have been able to determine. It has been clearly shown in the foregoing that infection can give the clinical picture of malignancy and these breasts will have to be sacrificed. For anyone who has tried to keep a draining sinus sterile, it is easy to understand the possibility of a high percentage of infection in these cysts. They are filled with a good culture medium, frequently there is a large dead space, with intermittent or slow discharge, and practically no attempt at asepsis. Fortunately, in most cases it is a very low grade affair, with a chronic inflammatory reaction, showing on microscopic examination, round-cell infiltration, with a few scattered polymorphonuclear cells. However, four of these cysts had ruptured, one on three occasions, and three patients came in with a draining sinus through the skin away from the nipple. Another case, diagnosed as abscess, showed all the signs and symptoms of acute inflammation, and the papillomas were discovered only on pathologic examination. One of these patients had intermittent attacks of conjunctivitis, and the organism, an unclassified bacillus grown from the nipple discharge, was found to be identical with what was apparently the etiologic agent in the eye condition.

Here it should be noted that we have no record of a patient with cancer coming in with a draining sinus. In the early cases a fairly large number showed ulceration and even now an occasional patient comes in with this condition. Of course one of these cysts, with an associated cancer or possible malignant degeneration, would be liable to develop a sinus from the rupture of the cyst, but we have not met with such an instance.

*Pathologic Observations.*—Associated with these tumors there is often an extensive epithelial hyperplasia which may assume one or more

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14. Bloodgood, J. C., cited by Kelly and Noble in *Gynecology and Abdominal Surgery*, Philadelphia, W. B. Saunders Company, 1908, vol. 2, p. 194.

3. Of the four patients with no note on the glands: two died of metastases one year after operation; one had had no recurrence after ten years and died of some unknown cause thirteen years after operation, and the other patient could not be followed.

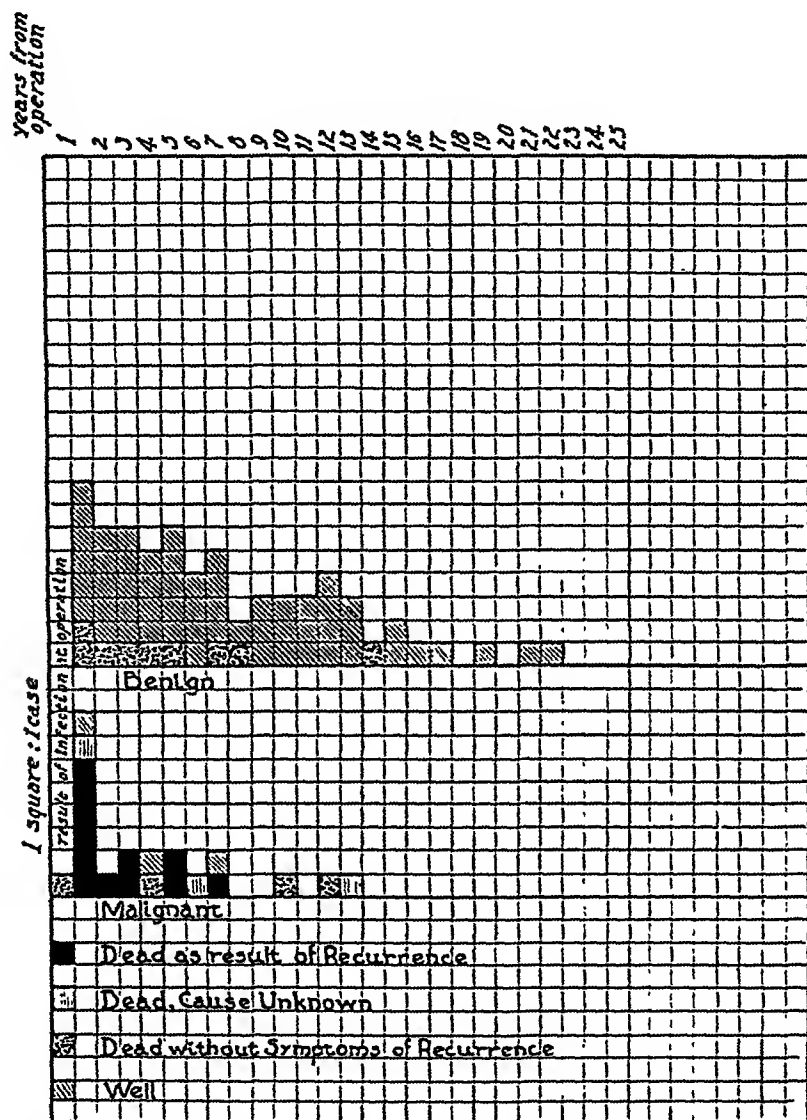


Fig. 18.—Carcinoma, papillomatous cysts and intracanalicular fibro-adenoma located in the same breast and in such proximity that all can be seen under one field of the microscope.

*Doubtful Group.*—No patients died of cancer or showed evidence of recurrence.

From this and from figure 18 it can be seen that among the benign cases there is no evidence of any patient having had a recurrence, while of the malignant group: twelve patients have died of recurrence, three of other causes and two of some cause not stated, during the period of

nant case we have of more than from five to six years' duration, and with a history suggestive of a cancer developing in a benign tumor. However, this is not such a high percentage of malignant change as one is led to expect from a study of the literature. Certain facts strongly suggest that the malignant cases, with the exception of the one referred to, were cancer from the onset. These facts are: (1) In fifteen of the twenty-one cases of cancer in which the duration is known, the patients came to operation within two years of the onset (fig. 3); (2) in only two cases was there a history of more than five years' duration (six and thirteen years, the latter case previously noted), and (3) in only 38 per cent of the benign group, with an average duration of 3.3 years, the tumors were 6 cm. or more in diameter, while in 70 per cent of the cancer group they had reached this size after an average duration of only 2.5 years.

*Comparison of the Impression Based on a Clinical Study with That Made at the Time of Actual Examination.*—From a study of the records of these cases, we find that in the cancer group there have been relatively few mistakes clinically and none pathologically. If the cases with marked infection are removed from the benign group, none of them gave a definite picture of malignancy. Certain cases were noted as suggestive of malignancy, but in reading over the histories and physical examinations in view of this study, we find that the impression has been based on such things as slight changes in the nipple, the firm, lumpy or nodular character of the tumor, the bloody nipple discharge, and so forth, which must be discounted, as is here explained. With this in mind, the findings are almost entirely more those of a benign than of a malignant tumor. The mistakes in the majority of cases have been due to the exploratory incision; the surgeon, finding bloody fluid or a papilloma, has immediately closed the incision and performed the more radical operation. At the present time, owing to the fact that all superficial tumors come earlier under observation, and because of the greater difficulty in diagnosing cancer at this stage, it is imperative that every definite nodule in the breast should be removed. This, from the patient's standpoint, puts the ultimate diagnosis up to the surgeon at the time he removes the tumor. He should have the pathologic picture of this tumor in mind whenever he makes an exploratory operation.

*Ultimate Results as Proof of the Correctness of This Division into Two Groups.*—In conclusion, it seems that the ultimate results (fig. 18) offer sufficient proof that our division into these two groups is in the main correct. Our cancer group with 50 per cent of the patients dead as a result of recurrence or metastases, three dead from other causes during the period of probable recurrence, two dead during this period from causes not stated, and with only three patients living at the present time, one, four and seven years after operation, is in marked

probable recurrence; three patients lived ten, twelve and thirteen years, respectively, while three patients are living and well one, four and seven years after operation.

#### EXPLANATION OF TABLE

The accompanying table covers the entire data in this article. Under both the benign and the malignant group is given in one column the number of cases, and in the other the percentages; the latter, according to the suggestion of Dr. Raymond Pearl, are based on the actual number of cases for which we have a definite note. This in general causes the percentages to be based on a summation of the figures in the first column for each major division. An exception to this is for the summation of the symptoms of tumor, nipple discharge and pain, in which the symptoms overlap, and the percentage is necessarily based on the total number of cases, since all the patients complained of one or more of these symptoms.

#### COMMENT

From our own records and from the literature it is evident that cases belonging to the benign group of these tumors have been most frequently misinterpreted and as a result a large percentage of the patients have been subjected to an operation more extensive than is justifiable except for malignancy. In the majority of cases this has followed either the excision of the tumor or an exploratory incision, since the lesions were clinically benign or only suggestive of malignancy. The more radical operative procedure has been based on the finding of a cyst filled with bloody fluid, and with a soft, friable, papillomatous tumor attached to the wall. Without further thought the surgeon has closed the wound and performed the radical operation or, being in doubt, has been content with that unjustifiable, halfway procedure of removal of the breast alone. The latter operation is evidently not radical enough for cancer but is too extensive for a benign lesion, save in the occasional case in which one or multiple tumors almost replace the breast.

There was one group of patients who gave the clinical picture of malignancy and who were submitted to the radical operation without exploration. This included a large part of the cancer group, and also those cases showing the more severe grades of infection. These benign tumors associated with extensive infection were the only ones of the simple papillomatous cysts that were clinically malignant. Since it was almost impossible to rule out cancer in these cases in which the breast contained large, cystic tumors associated with the superimposed infection that had produced an induration, thickening of the wall and adherence to the surrounding tissues, they had to be treated as cancer.



rounding tissues. In short, this was a case of a very small primary cancer growth, associated with benign tumors, and with extensive invasion of the lymph channels of the breast. The axillary dissection was performed soon afterward; the sections showed early involvement of all the adjacent lymph glands, with the lymphatics along the small vessels in the axillary fat plugged with tumor cells. In this case the operator's first and clinical impression of cancer was entirely overruled by a pathologic report from the examination of a small nodule not intimately associated with the true and really important tumor. On the other hand, when a careful gross examination shows a thin wall to a papillomatous cyst, freely movable over the surrounding structures, with no evidence of invasion at the attachments of the pedicles (figs. 6 and 7), the condition may be treated as benign regardless of what report the pathologist may make from an examination of the papilloma alone.

If a diagnosis of malignancy is made at *exploratory excision*, the wound should be cauterized and the complete operation immediately performed. If there is any doubt, the patient should have the benefit of the radical operation.

There will be a small number of cases that will present the earmarks of malignancy, and in these the complete operation is indicated. Some of these will prove to be cancer, but others will show infection of a benign papillomatous cyst. In the latter group exploration is practically useless, since the picture is so distorted, both grossly and microscopically, that the operator would probably still be in doubt unless he relied on the report based on a study of sections made from a block taken at random—a report that would be worse than futile.

Here it should be urged that after any examination of a gross specimen, particularly in the case of the papillomatous cyst, aseptic precautions should always be preserved. Since the most important thing is the examination of the specimen for diagnosis, and since this responsibility lies on the operator, it would be better for him either to drop out and have the wound closed by an assistant, or else after the examination of the specimen to change his gown and gloves. This is imperative, both because a soft, friable papilloma could be easily transplanted, and also because these cysts, connected with the surface by a duct, with a constant or intermittent discharge of contents, are particularly prone to infection, which, if transferred to the wound, would cause a breaking down of the incision.

#### SUMMARY

*Benign Group.*—The benign papillomatous cyst is a distinct type of tumor, presenting a fairly uniform history and physical findings. A nipple discharge, usually bloody, occurred in 66 per cent of these cases. This tumor sometimes gives a nipple discharge without a palpable nodule.

three years after the onset of menstruation. This ceased after a short time and a lump appeared, which gradually increased in size and was painful. We have no record as to the size the tumor reached, but the sections show extensive epithelial hyperplasia throughout the gland. Only the breast was removed, one year after onset, the patient being then 16 years of age. In 1923 the patient, then 17, returned with a bloody discharge from the right breast and some little nodules in the skin of the left chest. The right breast was removed in June, and three weeks later the tissues about the scar on the left chest and the left axillary glands. This last operation was performed because of the gross diagnosis of cancer and a microscopic report of papillary adenocarcinoma of the breast. The lymph glands were not implicated and unfortunately the skin nodules were lost, so that their character could not be determined. The case was diagnosed by us as multiple, benign, papillomatous cysts, and by Ewing as papillary cystadenoma. We feel that the extensiveness of the condition demanded removal of the breasts, but that the radical removal of the tissues from the left chest wall and the axillary dissection were not indicated. The burden of proof would certainly rest on the person who makes a diagnosis of cancer of the breast in a person of this age.

*Variation in Size of the Tumor.*—Mention is made in the literature of the variation in size. Bowlby<sup>12</sup> reported a case of spontaneous cure, which we interpret as meaning that the tumor disappeared. Williams<sup>1</sup> mentions a tumor which suddenly appeared beneath the nipple with a cessation of the discharge. This case is also cited by Deaver and McFarland. Greenough and Simmons<sup>6</sup> state that in some cases pressure caused a discharge from the nipple with a decrease in size and softening of the consistency of the lump. Such a discharge is of fairly frequent occurrence, and, when this history can be obtained, is suggestive of a cyst. Decrease in size associated with a nipple discharge and enlargement of the tumor when the discharge ceases means that we have a cyst connected with a duct. This condition is most frequently seen in the papillomatous cysts, and if the discharge is bloody, it is almost pathognomonic. A recent exception to this was a case of colloid carcinoma that involved the entire breast, with a breaking down and destruction of all the tissue up to the nipple.

*Discharge from the Nipple.*—The discharge needs no explanation when the cyst is formed by a dilatation of the ducts, and here, as with papillomas elsewhere, bleeding is the rule. The type of discharge sometimes varies from clear or amber to bloody, probably dependent on trauma to the tumor. Here it should be urged that a bloody discharge from the nipple, with no other clinical conditions, should demand close observation, but should not be considered an indication for operation.

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12. Bowlby, A. A.: St. Bartholomew's Hosp. Rep. 24:263-272, 1888.

**Size:** The tumor was large in a much higher percentage (70 per cent) of cases than in the benign group (38 per cent) despite their much shorter average duration.

**Infection:** These cystic tumors with a slow or intermittent discharge are very prone to infection. This in the benign cases may give the clinical picture of malignancy with lymph gland enlargement.

**Pain:** There was pain in 41 per cent of the benign and in 67 per cent of the malignant cases. This symptom brings the patient earlier for operation than tumor or nipple discharge.

**Radical Treatment in the Past:** In an unusually large number of cases of the benign group the patients have been submitted to radical treatment—40 per cent to amputation of the breast and 38 per cent to the radical operation with removal of the pectoral muscles and axillary contents for cancer. Most of the diagnoses of "cancer" or "suspicious of cancer" have been made at exploratory incision.

**Removal of the Breast Only:** This operation for a case "suggestive of cancer" is unjustifiable, being too little for cancer and too much for a benign tumor not involving the greater part of the gland.

**Diagnosis:** Clinical observation is conducive to more accurate diagnosis than is exploratory examination. The character and attachment of the cyst wall and pedicle of the papilloma are a more reliable aid in the diagnosis of malignancy than the cyst contents.

At the present time, since the patients come under observation earlier, making the diagnosis of malignancy more difficult, one is more apt to find cancer at the exploratory excision. The tumor should be excised and then thoroughly examined rather than explored.

**Ultimate Results:** Of the benign group 65 per cent of the patients were followed for from one to twenty-two years and none developed cancer. This, together with the fact that a large percentage of the patients who suffered from malignancy, died of recurrence, is offered as proof of the correctness of this division into two groups.

The malignant tumor is not cancer of a relatively low grade of malignancy. This impression has been founded on a study of cases of the benign tumor incorrectly diagnosed and placed with the cancer group.

#### REPORT OF CASES

For those who desire to study this question critically the following report of cases may prove helpful.

*Group I.*—Four cases have been removed from the malignant to the benign group, and thought to have been unquestionably diagnosed wrongly at first. In addition to these, so many other cases have previously been reclassified as benign, and the original mistakes in diagnosis at the present time are so evident, that to print reports of all these becomes superfluous.

cases reported in the literature the papilloma has projected from the nipple and has reappeared when cut off or cauterized. We have one section through a duct just at the nipple showing stratified squamous epithelium on one side and the papilloma arising from the adjacent duct epithelium (fig. 11), while in another case the growth was located entirely within the nipple.

*Multiple Tumors.*—From the accompanying table it is seen that these tumors are frequently multiple, particularly on pathologic examination. But if there were added to this table all the cases which showed in microscopic section the small papillomatous cysts about the larger tumor, the nine patients who at a later time underwent an operation for a similar tumor and the half dozen or more patients who had a subsequent bloody nipple discharge, almost undoubtedly due to a similar small papillomatous cyst, it would be evident that this is definitely a condition with a tendency to multiple separate tumors. This is well illustrated by the following cases.

#### REPORT OF CASES

**CASE 1.—History.**—C. F. M., a woman, aged 34, a few days before admission noted a bloody discharge from the left nipple, and her physician found two lumps. Examination in the Johns Hopkins Hospital dispensary showed two lumps in the left and one in the right breast, all freely movable, not adherent, encapsulated, nonfluctuant and located near the nipple.

*Gross Pathologic Examination.*—Nodules ruptured during removal, with discharge of a chocolate colored, cellular material, said to be "suspicious of malignancy." Accordingly, the lower, outer quadrant of the left breast, including the tumor area, was excised. (No note was made on the treatment of the tumor of the right breast.) Numerous cystlike nodules varying in size from a pinhead to 1 cm. in diameter could be felt; not all of these were removed. On section they were found to contain a chocolate colored fluid and cellular detritus similar to that found in the larger nodules.

Microscopic examination showed multiple intracystic papillomas.

The patient has been well since the operation in 1915.

**CASE 2.**—This patient is a physician and has kept a close observation on her breasts since onset. Our records show the following:

1909. Bloody discharge from the right nipple; no tumor. Patient placed under observation, but no operation.

April 23, 1913. Excision of a benign papillomatous cyst from the right breast was performed. The discharge had ceased about six months before, and following this the lump had appeared. Microscopic examination of the tumor showed the papilloma with a fine connective tissue stroma and a definite wall about the cyst. Outside the larger cyst there were other small papillomatous cysts, and lobules of breast tissue showing mastitis.

Jan. 24, 1914. The patient reported that there had recently been a palpable tumor in the left breast, but this had disappeared after being present for a few weeks.

April, 1917. Three months previously there had been a bloody discharge from the right nipple lasting a few weeks. Examination showed that both breasts were symmetrical and soft, the right breast showing the scar from the previous opera-

watery discharge from the nipple began six weeks before admission; there had been some pain since. Ulceration had been present for three weeks.

The nipple had entirely disappeared. An area of skin 8 cm. in diameter over the tumor was purplish, red, thin and adherent and ulcerated at the most forward point. Beneath this was a hard, irregular, nodular mass with a cystic center. From the sinus exuded a purulent discharge with white flakes of broken down "carcinoma." The remainder of this breast and the other breast were normal. There was a hard, freely movable lymph gland the size of a chestnut in the lower axilla. Clinically, the case was malignant.

The breast only was removed on account of the age of the patient, and the extensiveness of the condition.

Pathologically, the mass was definitely encapsulated, and there were numerous papillomatous growths in the cyst. Microscopic examination showed benign papillomas, infection, and what at that time was considered as adenocarcinoma. This area we now consider as a benign, cystic adenoma.

It has been impossible to trace this patient.

*Group II.*—Instead of an attempt to make a composite picture of an indefinite classification, the five cases in which the diagnosis is doubtful are given so that they can be read in detail. Certainly most of these cases are benign, since in general when pathologists disagree or are uncertain about malignancy the clinical course is more that of a benign condition.

CASE 5.—W. F. S., a woman, aged 47, had a tumor of the left breast of one year's duration, which had a bloody discharge from the nipple for eighteen months. No pain was felt, the tumor was irregular, nodular, the size of a chestnut, with dimpled skin and nipple elevated. A complete operation for cancer was done.

Pathologic examination showed a tumor about the size of a twenty-five cent piece, with remains of a cyst wall and suggesting infiltration in places. The tumor had the appearance of hemorrhagic medullary carcinoma, with the hardness of cancer. Microscopically it was said to be medullary carcinoma with minute cyst formation. The tumor was circumscribed. In some places it had a definite papillomatous arrangement. The glands showed no metastases.

To me this is definitely not medullary carcinoma, and I would call it benign. Bloodgood calls it a borderline group tumor.

The patient is well at present, two years after operation.

CASE 6.—W. F. M., a woman, aged 44, had a tumor present for six months, which rapidly enlarged to the size of a small orange, subsided under local applications with relief of the pain present during the distention. There was an associated discharge from the nipple.

Examination showed a nodule 2.5 inches (6.2 cm.) in diameter just above and to the outer side of the nipple. It had the hardness and irregularity of cancer, with slight atrophy of the subcutaneous fat. A complete operation for cancer was done.

Pathologic examination showed a cyst with smooth walls except for a thickening in the wall toward the nipple suggesting medullary carcinoma or adenocarcinoma, or possibly the base of a papilloma; but if the latter, the papilloma had disappeared. Microscopically it was said to be "typical of the adenocarcinoma of the papillary type." The lymph glands were negative.

ing nipple. At operation these tumors were found to be cystic and connected to the nipple by a definite cord, suggesting a duct, but no fluid could be expressed. It is evident that if in these cases one tests the nipples by lifting them, there may readily be found a certain amount of fixation. Some of the patients with retraction showed infection, and one had had the nipple retracted since the birth of her first child, sixteen years before. In two cases with the nipple obliterated, in addition to the tumor there was a marked inflammatory reaction.

According to Deaver and McFarland, the nipple is never inverted in uncomplicated cases. They cite, however, a case with the growth beneath, and with part of the papilloma projecting from the nipple and causing inversion. Ewing states that the nipple may be retracted.

*Consistency.*—The malignant group showed in general the consistency of cancer. Of the seven cases in our benign group in which the tumor was noted as indurated, four showed infection. The three remaining, together with the thirty-three noted as firm, nodular or shotty, can be easily explained by anyone who has felt a tense cyst in the breast, if he but imagine this surrounded by multiple small tumors of a similar character, which are usually found on pathologic examination. The two cases noted as "hard, like cancer" both showed infection. Greenough and Simmons state that they are hard if tensely filled with fluid. Deaver and McFarland state that they are generally irregular, lobular or lumpy, the majority giving the impression of solid tumors.

*Mobility.*—Only one of the benign group showed attachment and in this case there had been an extensive infection, and the mass had ruptured before the patient came under observation. In about half the malignant group in which a note was made on mobility, the tumors were attached. Where noted in the literature these tumors, whether diagnosed as benign or malignant, were freely movable except in occasional cases, which from the history and findings suggest cancer.

*Lymph Glands.*—The lymph glands were essentially negative in the benign group except in one case with marked infection, in which the glands are recorded as "hard, like cancer." Despite the clinical diagnosis of malignancy, on account of the age and feebleness of the patient, only the breast was removed. The existence of a benign papillomatous cyst with infection is now generally recognized. Unfortunately, we have been unable to trace this patient, she having been treated in the early days of the hospital. In nine cases the glands are recorded as palpable, but frequently with the note that they are not hard, like cancer, and wherever the glands were studied pathologically they showed no metastases. When one considers the number of these cases with infection, it is surprising that not more of these patients had enlargement of the axillary lymph glands. On the other hand, 50 per cent of the malignant

Pathologic examination showed a cyst with an intracystic papilloma. It was diagnosed as malignant, though there was no microscopic evidence to confirm this.

The patient died three and one-half years later. A note was made that death was not due to cancer and that there had been no return of the trouble.

*Group III.*—The two cases of intracanalicular fibro-adenoma ran a clinical course similar to that of true papilloma, and on casual gross examination could well be confused with it. They have likewise been classified with this type of tumor, present the same problems, and in both of these cases malignancy was originally diagnosed.

CASE 10.—The revised diagnosis in this case was intracanalicular myxoma growing in a cyst and suggesting an intracystic papilloma. The first diagnosis had been a benign growth of the breast, a papillomatous cyst of the intracanalicular type. The adenomatous part showed carcinoma. (The "carcinoma" was afterward erased and "benign" written over it.)

W. F. S., a woman, aged 26, had a tumor which was first observed eight years before admission, when the patient was 18 years of age. With the first pregnancy eighteen months before admission, this breast secreted no milk but there was a more rapid growth of the tumor. Her second pregnancy was of seven months' duration, and the tumor had grown quite rapidly during this time. Four months before admission a sinus formed, which was thought to be tuberculous. The entire breast was removed without axillary dissection. No note was made as to the discharge from the nipple, but the cyst did not contain blood after the operation.

Pathologic examination showed a sinus in the skin, leading down to the cystic cavity, which had a smooth wall and contained a papilloma, nodular in type, about the size of an orange, and having the appearance of the intracystic growth of an intracanalicular myxoma. There was no infiltration beyond the wall.

Microscopically areas with irregular cells were seen and some cellular areas which might be suggestive of early malignancy. A note by Bloodgood later stated that this area marked "suspicious of malignancy" showed distortion due to a chronic inflammatory reaction and was benign. Study at the present time shows a typical intracanalicular myxoma with a chronic inflammatory reaction, manifested by a quite marked round cell infiltration and an occasional polymorphonuclear cell. There are remnants of epithelial structures, the cells having more the appearance of breast acini in infected tissue, and through these areas there are quite numerous small, and apparently newly proliferated blood vessels with large endothelial cells. Certainly the picture does not suggest carcinoma.

CASE 11.—The diagnosis was benign tumor of the breast; intracanalicular myxoma, with a large pedunculated tumor, projecting into a cyst, suggesting an intracystic papilloma.

W. F. S., a woman, aged 22, had a tumor in the upper outer quadrant of the left breast of two years' duration. She had pain for two months, during which time the tumor had grown rapidly. The tumor was excised under local anesthesia. It contained blood tinged fluid and a cauliflower-like growth attached to the cyst wall. The operator, being in doubt as to the nature of the condition, then removed the entire breast, but no other lumps were found, and he states that the axillary glands were not palpable. The specimen was received with the question, "If this is cancer should the complete operation, with removal of the pectoral muscle and axillary dissection, be done?"

of several forms. It may be simply a part of the condition that causes the multiple papillomas. There are two pictures, however, for which it is interesting to attempt an explanation.

One is the glandlike arrangement of the papilloma in places (fig. 8), and seems to us to be due to the manner of cutting the sections, or dependent on the fact that the various papillae have become adherent and fused, with a loss of the epithelial cells at the point of fusion. Similar pictures are frequently seen in the fallopian tubes following an inflammatory lesion. The other is the hard area with a rough resemblance to scirrhus carcinoma (fig. 13). It seems that this could well be explained by the entanglement of certain epithelial elements and their inclusion in the formation of fibrous tissue, the latter reaction dependent on an irritation, either from the tumor and associated hemorrhage into the tissues, or from infection superimposed on the papillomatous cyst.

*Probability of Malignant Change in the Benign Group.*—These tumors have been looked on as especially liable to malignant degeneration, and, as for all breast tumors, their removal is demanded when there is a definitely palpable tumor. From figures 3 and 4 it can be seen that there are thirteen patients in the benign group who had had a tumor of from five to twenty-five years' duration and six with a nipple discharge extending over a similar period. Furthermore, one of our patients, aged 72, who had had a papillomatous cyst with a bloody discharge for one year, stated that her mother, then 96 years of age, had had a cystic tumor for many years, with onset soon after the menopause, associated with a continuous discharge from the nipple, the character of which had varied between bloody and serous. Her mother's health was good. There also were several cases cited in the literature with a duration of from ten to thirty years. On the other hand, we have one patient who gave a history of thirteen years' duration, with slow growth to the size of a walnut at the end of eleven years. At this time it was cut into, without an anesthetic; only bloody fluid was obtained, and no further treatment was carried out. There was no history of nipple discharge. After that time it had grown rapidly, increasing 300 per cent in size within two years, and a prickling pain had been present for three weeks before admission. Examination showed a tumor in the outer half of the breast, attached to the old scar, and below this a large cystic swelling. It was associated with enlarged axillary glands, and was diagnosed clinically as carcinoma with cystic degeneration. The radical operation was performed and the specimen showed, grossly and microscopically, cancer in the mammary gland and axillary lymph nodes. In the breast it was intimately connected with a cyst which was filled with bloody fluid and in which there was a projecting papilloma. The patient died recently from an extensive recurrence. This is the only malig-



# CARCINOMA OF THE MALE BREAST

## CLINICAL AND PATHOLOGIC STUDY

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## HISTORICAL

Ambrose Pare (Paris, 1510-1590), Thomas Bartholinus (Copenhagen, 1616-1680) and Ledran (Paris, about 1778) are said to have written of carcinoma of the male breast, but it has not been possible to consult these articles. About 1820, articles on the subject began to appear in medical journals, especially in the *Lancet*. Liston (*Lancet*, 1838), one of the notable earlier reporters, while operating on a man said: "Those who witnessed the operation observed that I was at no pains to preserve integument." A somewhat naive remark which I think might well receive more consideration today. From 1820 to the present day, articles have frequently appeared, especially in the French, English and American journals. German contributions have, singularly, been infrequent. Horteloup<sup>1</sup> collected seventy references to diseases of the breast of all kinds in man. Velpeau<sup>2</sup> mentions, without going into detail, ten cases of carcinoma in men in about 2,000 cases of various conditions of the breast. In 1844, Walsh,<sup>3</sup> quotes Velpeau as saying that he has "never seen and neither do other writers quote any examples of the dissemination of these tumors (i. e., male breast carcinoma), or of their being reproduced in the viscera or other parts of the economy in men as in women." Velpeau, in 1854, admits this as his previous opinion, but says, "I would not say this as before . . . as I have several times had occasion to prove the contrary since."

The earlier writings were largely reports of single cases. The first systematic study of carcinoma of the male breast was published in 1883 by Paul Poirier.<sup>4</sup> Poirier's introductory paragraph is such a fine example of French completeness and clearness that it is quoted in full.

The condition more often begins in the second half of life, 45 to 65 years. It begins ordinarily as a small limited induration, under or near the nipple. It remains in this state sometimes for a considerable period without causing appreciable pain and without affecting the general health. Then suddenly, after six months to five years, the tumor increases in volume and soon is the

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1. Horteloup: Thèse de Paris, 1872.

2. Velpeau: *Maladies du Sein*, 1854.

3. Walsh: *Anatomy, Physiology and Treatment of Cancer*, 1899.

4. Poirier: *Paris Thesis*, 1883.

contrast to the widespread impression that these are tumors of a relatively low grade of malignancy. It seems clear to us, however, that this impression has been founded on mistaken diagnoses in which many of the benign cases have been called cancer.

#### METHOD OF ATTACK AT OPERATION

Based on the foregoing study, the following method of attack is suggested as offering the best chance of proper treatment. If the tumor is definitely malignant clinically, the radical operation should be performed without an exploratory incision. If it is thought to be benign, or if there is only such suspicion of malignancy as to demand exploration, and the tumor is not of such a size as mechanically to demand the removal of the breast, it should be *excised* with a zone of surrounding tissue. It should be immediately sectioned and examined for malignancy. Here one should be familiar with all that is included under the pathologic examination and should examine for the thickness of the cyst wall, its character, mobility of the wall over the surrounding structure, and should note particularly the attachment of the papillomas to the adjacent structures.

From any suspicious areas, either of increased firmness, unusually firm attachment of the pedicle of the papilloma, or where there is a question of invasion of the surrounding structures, blocks should be taken and sections made immediately. These sections should show the base of the pedicle and the tissue from which the papilloma arises. One section taken at random by the operator without seeing the entire specimen, or by the pathologist, without a careful gross examination of all the tissue, is worse than useless. It may give a false impression of benignity; or, if from the papilloma, it may be diagnosed as cancer, when the tumor is encapsulated, lying in a cyst with thin, smooth, freely movable walls. In this connection we might cite a recent case, not of papillomatous cyst, in which the operator, on demand of the patient, explored a breast tumor that was clinically malignant; he came down on a definite nodule lying on the edge of an indurated area in the breast. This small tumor was excised from the surface of the larger mass, and the operation delayed for the frozen sections which showed a typical intracanalicular fibro-adenoma. (Figure 17 is a similar case in this series.) The operator accepting this diagnosis of a benign tumor, and thinking that the involved area was so large as to include most of the gland, amputated the breast alone. Pathologic examination a few minutes after the close of the operation showed on one side of the tumor mass an area measuring from about 1.5 to 2 cm. in diameter, which was considerably harder than the surrounding tumor and which had a gritty consistency. On running the finger across it, one could mark out one border as definitely as the edge of a wooden shelf; on the other side it shaded off into the sur-

The age at the time of observation is given in 401 cases. The average age is 54.2 years. Lane-Claypon does not give the average in her large collection of statistics on women, but in table 1 she does give an elaborate classification by semidecades and a comparison of the data on men.

It has frequently been noted by others that carcinoma of the breast develops later in men than in women. This apparently is borne out by the foregoing. Most cases occur in women between the ages of 45 and 49; in men, between the ages of 60 and 64; about one half of the women and about two thirds of the men are over 50.

The youngest patient among the men is difficult to determine with certainty. Blodgett<sup>8</sup> gives a brief report of a case in a boy, aged 12. The duration of the condition and the microscopic report were not given. An operation was performed, and the patient was well five years

TABLE 1.—*Ages at Operation (Or Coming Under Observation of the Reporter) Percentages for Each Quinquennial Period.*

		Age Periods																
	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	90 to 94	
Lane-Clayton 8,053 women	1	1	0.1	1.0	3.9	8.4	14.7	18.3	17.2	13.4	11.2	6.8	3.4	1.2	0.2	0.2	...	
Present series																		
401 men	0.5*	0.2*	1.5*	0.7	1.5	5.7	8.7	14.0	13.2	16.2	17.2	9.2	8.0	2.0	0.75	0.25	2.5	

\* These cases in very young patients are discussed below.

later. Simmons<sup>9</sup> reports a case in a boy, aged 13, who was operated on when he had had a carcinoma for one year. The pathologic diagnosis was adenocarcinoma of the breast of a medullary type. The patient was well, January, 1926, nine years after the operation. Bryan<sup>10</sup> reports a case in a boy, aged 14 years and 8 months, who developed a tumor following a blow by a golf ball. After a duration of six months the patient was operated on. A pathologic diagnosis showed adenofibroma with "distinct scirrhus carcinoma in a scattered area of active proliferation." The patient was well in 1926, thirteen years after operation. None of the foregoing cases sound convincing, and as slides are not now available, they should be considered as not proved.

Coley<sup>11</sup> reports a more definite case in a man, aged 22. After a duration of three years an operation was performed. There was a prompt recurrence of the tumor followed by a second operation and a

8. Blodgett: Boston M. & S. J. 136:611, 1897.

9. Simmons: Adenocarcinoma, J. A. M. A. 68:1899, June 23, 1917.

10. Bryan: Surg. Gynec. Obst. 18:545, 1914.

11. Coley, W. B.: Ann. Surg. 31:741, 1900.

This discharge alone demands close observation, but is not an indication for operation.

**Age:** Tumors of the benign group in our series have appeared at any age after puberty; the malignant only after 35 years of age (one case suggestive of malignancy in a patient of 27).

**Sex:** They are rarely found in the male breast (2 per cent).

**Duration:** They may be of any duration; some in this series were present for from twenty to thirty years.

**Consistency:** They may have a firm, nodular and indurated consistency, due to multiple cysts, tensely filled with fluid and so situated as to suggest a single tumor.

**Location:** They occur predominantly in the central zone of the breast, but occasionally in the periphery.

**Number:** Clinically, they occurred as a single tumor in 83 per cent of the cases but other tumors developed later in 15 per cent. The specimens showed other tumors, on pathologic examination, in about 50 per cent of the cases.

**Size:** They usually are small, but they were over 6 cm. in diameter in 38 per cent of the cases.

**Nipple:** There may be some retraction of the nipple due either to the mechanical action of the tumor in pressing on the ducts, or to the contraction of scar tissue where infection is superimposed.

**Skin:** The skin usually is normal, but may be tense, thin, shiny, red, or show a sinus from rupture.

**Variation in Size:** Change in size of the tumor associated with a bloody nipple discharge is almost pathognomonic of a papillomatous cyst.

**Pathologic Examination:** There usually is a cyst with one or more papillomas, a thin wall and no invasion. Frequently there are multiple cysts and about these all types of epithelial proliferation, duct adenoma, cystic adenoma and nonencapsulated adenomatous areas, with associated hemorrhage into the tissues or a superimposed infection, these giving a fibrous proliferation.

**Malignant Group.**—A large percentage of the cases in the malignant group gave the picture of cancer, clinically, grossly and microscopically.

**Origin of the Malignant Tumors:** The cancer may apparently arise from a papillomatous cyst, or occur in a breast the seat of one or more of these tumors.

**Duration:** The duration usually is short, but in one case the tumor was present for thirteen years, suggesting a benign growth for eleven years, with malignant change about the time of, or following incision. No other patient gave a history that would suggest malignant change in a benign tumor.

The cases in which a long duration of the tumor is alleged are of especial interest. The five cases in which the duration is from twenty to thirty-four years are given in detail in table 3.

In these cases in which the patient's condition was of long duration it is more probable that the tumor originally noticed was benign and changed to carcinoma later. Occasionally the course is slow in cases that are definitely cancerous from the beginning. Even so it is hard

TABLE 2.—*Stated Duration of Tumor at Time of Observation by Periods of Time*

Time	Percentage of Total
0 to 6 months.....	23.3
7 to 12 months.....	23.3
13 to 23 months.....	7.9
2 to 3 years.....	25.8
4 to 5 years.....	8.5
6 to 9 years.....	4.4
10 to 14 years.....	3.0
15 to 19 years.....	1.4
20 to 34 years.....	1.4

TABLE 3.—*Details of Cases With an Alleged Duration of From Twenty to Thirty-Four Years*

Reporter	Age at Observation	Alleged Duration, Years	Beginning of Rapid Growth	Ulcerated	Axilla Involved	Slide Verified in This Study	Type	Estimation of Malignancy	End Result
Auchincloss.. (New York)	53	20	1 year	No	Yes	Yes	Sclerithus	Medium	Well 27 months after operation
Roberts..... (Toronto)	69	25	Pain last 2 years	No	Yes	Not available	.....	.....	Died 6 years after operation at age 70; said to be free from cancer
Greenough... (Boston)	57	25	.....	Yes	Yes	Not available	.....	.....	Inoperable; died
Warfield..... (Milwaukee)	47	26	3 years	Yes	Yes	Yes	Sclerithus muscle involved	High	Died 5 months after operation; metastases
Jennuency... (Bordeaux)	61	34	2 years	No	Yes	Yes	Squamous epithelioma	Low	Well 26 months after operation

to believe that in four of these cases the condition should still have been operable twenty, twenty-five, twenty-six and thirty-four years, respectively, after first being noticed, if the tumors were carcinomatous from the start. Robert's patient gave the following history: "twenty-five years ago the nipple began to draw in and it gradually entirely disappeared and the skin grew over it. After fifteen years a wart-like mass appeared where the nipple had been and slowly grew till it was the size of a finger nail. It was not ulcerated or cracked."

The three slides of these long-standing cases which have been restudied do not indicate a previous benign tumor.

CASE 1.—A white married woman, aged 71, complained of a burning sensation in the left breast of four weeks' duration. Examination showed a hard, indurated mass, about the size of a walnut, just outside the nipple, with no other evidence of malignancy in the nipple, skin or axillary glands. A complete operation for cancer was performed.

Pathologic examination showed a cyst, 2 cm. in diameter, near the nipple, filled with a bloody, jelly-like material, on removal of which the wall was seen to be lined with a ragged growth. There was no apparent infiltration outside the cyst wall. Microscopic examination showed the wall composed mostly of granulation tissue, with some evidence of a papilloma. Sections through the thick part of the wall of the cyst showed granulation tissue and papilloma, with the basement membrane of the duct gone. It was thought at the time to suggest carcinoma, and is now thought to be a papilloma with infection. The glands showed no metastases.

The patient, when last heard from two years after operation, was well.

CASE 2.—W. F. M., a woman, aged 45, had a bloody discharge from the left nipple occurring at intervals for eleven months. A tumor the size of a walnut was noted for three months with gradual increase in size. There was no pain. The positive physical findings were a firm, non-tender, irregular mass, about 6 by 4 by 4 cm., freely movable over the chest wall and fairly movable through the breast tissue, with some atrophy of the subcutaneous tissue and with slight dimpling of the skin with displacement of the tumor. The left nipple could not be pulled out quite as far as the right, and the left breast was at a little higher level. The lymph glands were negative. A complete operation for cancer was performed. No note about an exploratory incision was made.

Pathologically, there was a firm, fibrous tumor, showing a smooth walled cyst containing blood. At one end was another tumor and through this were numerous channels from 1 to 3 mm. in diameter, some filled with blood, and others containing a granular, cellular tissue. In sections one sees the ductlike spaces filled with epithelial debris, and in some a distinct papilloma. At the time this growth was thought to be suggestive of malignancy, but is now thought to be benign. The patient is well at the present time, eight years after operation.

CASE 3.—C. F. M., a woman, aged 50, had a lump in the right breast of one year's duration. There had been a slight increase in size, and pain for nine months. No nipple discharge was noted. Examination showed the right breast hanging 1.5 cm. higher than the left, with a fulness over the lower part. The skin over this was a trifle shiny and below this was a small dimple. The mass was hard, irregular and very tender. The glands were negative. Clinically the cyst was benign.

Exploration was done and a complete operation for cancer performed.

Pathologic examination showed a tumor with three distinct lobules, each with a distinct wall. Within the cysts was hemorrhagic tissue, having a papillomatous arrangement. Microscopically, it showed a papilloma and seemed to be infiltrating outside the cyst wall. A note says that it would have to be called histologic cancer, though all similar cases had shown no metastases to axillary glands and all the patients had remained well. The glands were negative. It is now thought to be benign and not an invasive tumor.

The patient was well when last heard from in 1920, six years after operation.

CASE 4.—W. F. M., a woman aged 76, had a tumor for from twenty to thirty years which had increased gradually in size. No pain had been present until a

tumor has been present several years without ulceration. Table 3 shows three patients with tumors of twenty, twenty-five and thirty-four years' alleged duration which were not ulcerated, clinically. The size of the tumor does not seem to influence the question of ulceration. Sumner (personal communication) reports a tumor the "size of a base ball" which was not ulcerated. Jeanneney shows a profile photograph of a tumor that must have been just as large, which also was not ulcerated. Ullman reports a tumor "larger than a baseball" which was not ulcerated.

*Axillary Involvement.*—The axilla is mentioned in 331 cases. It was involved in 228 or more than two thirds of the cases noted. The same objection to this comparison holds as in ulceration. Of the total 418 cases, the axilla is definitely stated to be clinically involved in 54 per cent. Microscopic examination of the axillary glands is not mentioned often enough for analysis.

*Trauma.*—Unfortunately in the earlier abstracts of the literature a reference as to trauma was not regularly recorded, so that of the 264 cases in the literature note of a definite statement as to trauma is found only in eleven cases. It is equally unfortunate that in the blanks on which the communicated cases were received a question as to trauma was not included so that it is only casually mentioned in four cases. However, even with this meager data, I am impressed with the recollection that trauma is mentioned so frequently and so connectedly that it must be taken into consideration as a cause of carcinoma, at least in the male breast. In some cases there has been a constant trauma from tools as in shoemakers and carpenters, and in other cases there has been a single blow. Billroth reports a case of gunshot wound of the nipple. A carcinoma was noticed in the scar six months later. Lilienthal, New York (personal communication), reports a case in which a piece had been torn from the nipple fifteen years before. A crust formed, and the nipple became contracted. One case is reported following a sword thrust.

Murphy,<sup>15</sup> in discussing carcinoma in a man, said "In the breast carcinoma is very frequently the sequence of a mild trauma of single occurrence . . . It is the only place in the body where this is so." It is not improbable that in women, too, trauma would be accorded a more important effect if histories were more carefully taken with this point in view.

#### SYMPTOMATOLOGY

Symptoms in carcinoma of the breast in men differ from those in carcinoma of the breast in women only in frequency and in time of onset. Ulceration is more common and tends to appear earlier; pain is more common and appears earlier. A discharge from the nipple is

15. Murphy: Surg. Clin., Chicago, 3:569, 1914.

Sections showed only the papilloma that Bloodgood says is hard to differentiate from cancer. To me it is more suggestive of a benign condition, though it is very hard to differentiate when only the intracystic growth is given.

The patient wrote in 1913, four years after operation, that she "is feeling fine, and the operation is a success in every way."

CASE 7.—W. F. M., a woman, aged 65, had a tumor of the left breast about the size of a robin's egg when first noticed seven months before admission. It was a slow growth until about one month before admission, since which time it has been rapid. The patient had had great anxiety and this was thought to have caused considerable loss of weight. On examination she was somewhat emaciated and had a tumor of the left breast the size of a hen's egg, firm, freely movable, not tender and with no change in the skin, nipple, axillary glands or subcutaneous fat. Amputation of the breast, without the sheath of the pectoral muscle, was done and axillary dissection for cancer.

Pathologic examination showed a cyst, divided into two compartments, with a wall from 1 to 3 mm. thick, except next to the septum, where it was about 2 cm. thick and composed of soft, friable tissue. A few calcareous deposits were present. Microscopically it was called an adenocarcinoma.

In sections taken from the thickened septum and papilloma Bloodgood diagnosed cancer. To me they show a dense fibrous tissue with scattered clumps of epithelial cells, which under the dissecting microscope seems to belong to the papilloma with areas of fibrosis. I am inclined to consider it benign.

The patient died eight years after operation, without further trouble. The registered cause of death was "uremia, secondary to an interstitial nephritis; and pernicious anemia, the latter recognized one year before death."

CASE 8.—W. F. S., a woman, aged 64, had a lump the size of a thumb in the upper outer quadrant of the left breast. It had been noticed six months before admission. There was no pain or tenderness. There had been rapid recent growth.

Examination showed a tumor 7 by 7 cm., irregular, hard and covered with large nodules. The nipple was normal, the skin tense, but not bound down, the veins large and prominent, and the whole tumor freely movable over the chest wall. There were many small nodules over the mass, some of them fluctuant. They were tender on palpation. No enlarged glands were noted. An exploratory incision was made and a complete operation for cancer was performed.

Pathologic examination showed a cyst containing a hemorrhagic grumous material, and a "definitely carcinomatous nodule on one portion of the wall;" otherwise the wall was smooth. Axillary glands were not enlarged. Microscopically it was said to show adenocarcinoma in the wall of the cyst. The axillary glands were negative. To me at the present time there seems a possibility of the growth being a papilloma, with infection superimposed.

The patient was well up to 1919, thirteen years after the operation, except for paralysis which had been present since 1915.

CASE 9.—W. F. M., a woman, aged 27, had a tumor of nine months' duration. It was the size of a walnut when first noticed; had a gradual growth for seven months, and a rapid one for the last two months, with much pain in the breast and arm. There was an associated discharge from the nipple for nine months. Examination showed a tumor occupying the outer hemisphere pressure on which caused a discharge of a rusty colored fluid from the nipple. The axillary glands were enlarged. The nipple was not retracted. A complete operation for cancer was done.



Microscopically, the male breast consists of a compact mass of dense connective tissue. Areas of whitish breast tissue spreading irregularly through fat are not seen. The connective tissue is irregularly interspersed with ducts which are represented by thin lines of two layers of flattened epithelial cells rarely showing any tendency to lumen except near the nipple, unless there has been a chronic inflammatory process with partial or complete obstruction to the ducts, in which case they are dilated and much resemble the female ducts. Anything approximating the racemose type of gland structure with lobules and ultimate acini as in the female is not described in the literature, and I have not seen this in numerous male glands removed at autopsy.

The present pathologic study is based on the somewhat unique opportunity of studying, restudying and comparing during the past four years a collection of slides from seventy-nine cases of carcinomas of the male breast.

Perhaps the most striking impression obtained from the study of these seventy-nine cases is that the fully developed late cases are not distinguishable from the carcinomas in the female breast. It is doubtful whether a pathologist would suspect that any slide in the collection did not come from the female breast. This similarity of the developed type in the two sexes adds considerable weight to the generally prevailing view that even in women carcinoma of the breast usually arises from ducts. If, as is also generally agreed, acini are not found in the male breast, the point of origin of the cancer in both sexes is the same and naturally the end-product would be similar.

#### CLASSIFICATION

The classification suggested by McFarland<sup>17</sup> will be followed here. Except in a few cases in which classification was not practicable on account of poor sections or faded stain, the slides studied seem properly to be classified as in table 4. All subvarieties are grouped exactly as by McFarland, with the exception that basal cell tumors are added to group 6. The squamous and basal cell types probably arise from the more superficial portion of the ducts, as well as from the surface epithelium of the nipple.

It is not best to compare this table too closely with McFarland's table for women; in general, however, it would seem that the scirrhus, medullary and squamous types are more common in men. Carcinoma simplex is less common in men. The figures for adenocarcinoma are about equal.

Basal cell epithelioma of the nipple is not mentioned by McFarland. The only patient in the present series who had this type of carcinoma

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17. Deaver and McFarland: *Surgery of the Breast*, Philadelphia, P. Blakiston's Sons & Co., 1917.

The cyst was small, 3 by 5 cm. in diameter, and was said to contain blood tinged fluid; it was excised with a small zone of surrounding tissue. Projecting from one side was a polypoid, cauliflower-like growth. The wall of the cyst was otherwise smooth, glistening and quite loosely attached to the surrounding breast. A microscopic section through the base of the pedicle showed that there had been no invasion of the surrounding tissues, and further sections proved that there were other smaller cysts, similar to the larger, and with pedunculated growths from the wall. The growth was a typical intracanalicular myxoma, with no evidence of malignancy or suggestion of invasion.

TABLE 5.—Details of Proven Cases Alive at Present Writing (2-15-27)

Date of Operation	Operator	Reference	Case Designation	Age at Operation	Pathologist	Pathologic Type	Auxiliary Glands Involved	Ulceroated	Malignancy Classification	Date Reported Well	Duration before Operation	Survival After Operation		Total Survived Before and After Operation		Slide Examined and Proved in Present Study
												Yrs.	Mos.	Yrs.	Mos.	
5/23/11	Italg...	Personal communication	W.F.M.	55	Ehman	Squamous cell	No	No	Low	2/15/27	3 mos.	15	9	16	0	Yes
10/ 1/13	Hubbard...	Personal communication	M.N.	73	Whitney	Medullary	Yes	No	—	1/20/27	4 mos.	13	3	13	7	No
5/ 5/15	Mackenzie...	Personal communication	N.	50	Bloodgood	Adenocarcinoma	No	No	Low	11/ 7/25	3 mos.	10	6	10	9	Yes
8/ 7/17	Berg...	Personal communication	J.G.	..	Mandelbaum	Medullary	?	?	Medium	1/ 7/26	?	8	5	8	5	Yes
5/21/19	Deaver...	Personal communication	J.F.	63	Reiman	Simplex	Yes	Yes	Low	1/10/27	15 yrs.	7	8	22	8	Yes
7/ 7/19	Judd...	Surg. Gynece. Obst. 42: 16, 1926	No. 5	45	?	?	No	?	High	1925	2 yrs.	5	?	7	?	No
5/23/20	Berg...	Personal communication	K.	53	Mandelbaum	Medullary	?	?	Low	2/ 7/26	?	5	9	5	9	Yes
9/17/20	Lee...	Personal communication	J.O'N.	42	Ewing	Adenocarcinoma	?	?	?	1/20/27	2 yrs.	6	4	8	4	No
1/10/21	Colvin...	Personal communication	.....	57	?	Medullary	No	No	?	1/24/27	5 mos.	6	0	6	5	No
1/25/21	Wood...	Personal communication	J.O'O.	70	?	Scleritis	Yes	No	High	1/15/27	15 yrs.	6	0	21	0	Yes
6/22/21	Buchanan...	Personal communication	J.O.	65	?	Simplex	No	No	Medium	10/14/26	2 yrs.	5	1	7	4	Yes
9/22/21	Adair...	Personal communication	S.A.A.	61	Ewing	Medullary	No	No	Low	2/ 1/27	4 yrs.	5	5	5	9	Yes
7/ 7/21	Coley, R.	Am. J. Surg. 40: 93	O.B.	61	Jeffries	Scleritis	No	No	High	2/ 7/27	6 yrs.	6	?	12	?	Yes
2/ 1/22	Cheever...	Personal communication	.....	58	Wolbach	Scleritis	No	No	?	1/20/26	1 wk.	3	5	3	5	No
5/ 3/22	Holman...	Personal communication	J.L.	63	Bloodgood	Scleritis	Yes	Yes	Low	6/21/26	3 yrs.	4	2	7	2	Yrs
8/17/22	Muschowitz...	Personal communication	S.	39	Mandelbaum	Medullary	No	No	Medium	1/18/27	Few days	1	7	4	7	Yes
1922	Judd...	Surg. Gynece. Obst. 42: 16, 1926	No. 17	60	?	?	No	?	High	5/ 3/26	2 yrs.	4	?	6	?	No
1/21/23	Whipple...	Personal communication	W.M.	61	Clarke	Adenocarcinoma	Yes	No	Low	1/ 8/26	3 yrs.	1	0	6	0	Yes

size of a nut or an egg. The skin becomes adherent and dimpled. The nipple retracts and becomes buried. The tumor becomes hard and nodular. Ordinarily about this period one or two glands appear in the axilla, sometimes they are connected to the tumor by a nodular cord. Quite often one now sees small nodules or tubercles appearing around the tumor, they have the characteristics of the principal mass. The patient now begins to complain of lancinating pains. Then only the skin, distended and adherent to the tumor, reddens and perforates, there is ulceration; the ulcer is excavated, the borders hard, the base is firm, it increases slowly and it may be the seat of hemorrhages. Such is the picture which presents ordinarily. The general health is good for a long time, progress is always slow. This clinical type corresponds to the anatomical form which we have described under the name of scirrhus carinoma. But other cases with a different histological structure progress more rapidly. They are much more rare.

Another elaborate study by Schuchardt<sup>5</sup> appeared the following year, and in 1894, the subject was again discussed at length by Williams.<sup>6</sup> This is the only textbook I have seen in which carcinoma in the male breast receives any systematic notice.

The present inquiry is based on an exhaustive study of the literature. All titles in the *Surgeon General's Index* and the *Index Medicus* have been personally consulted, with the exception of about a dozen articles in unavailable journals or in impossible languages. The total references personally consulted number 166. These articles have yielded a total of 264 cases reported in sufficient detail to be interesting. Cases merely mentioned and not accompanied by data have not been included. The original reference has been consulted in nearly all of these cases; all of the notes have been indexed, and duplication carefully avoided. In addition to the cases in the literature, I have compiled from hospitals and personal communications a total of 154 cases. Thus, a total of 418 more or less well detailed reports forms the basis of this study. Slides of seventy-nine cases have been borrowed or restudied in various laboratories.

#### STATISTICAL STUDY

In order to increase the interest of the statistical data, comparisons will be made with statistics concerning carcinoma in the male breast by Williams<sup>6</sup> and with statistics for the female breast by Lane-Claypon.<sup>7</sup>

In the present compilation, the side is mentioned in 336 cases as follows: right 163, left 170, bilateral 3; Williams reported: right 38, left 33; Lane-Claypon reported in women (twelve different countries): right 6,907, left 7,002. It would appear therefore that in both men and women there is a slight preponderance for the left side.

5. Schuchardt: *Arch. f. klin. chir.* 31:1, 1884.

6. Williams, W. Roger: *A Monograph on Diseases of the Breast*. London, 1894.

7. Lane-Claypon: *Reports on Public Health. Medical Subjects*, no. 28, Ministry of Health, London, 1924.

Several points of especial pathologic interest are illustrated in the accompanying photomicrographs.

#### THE END-RESULT

The end-result is known in 163 cases. Forty-one patients were alive at a recent date; ten patients died after the operation. Accurate data as to the total duration in patients surviving operation have been obtained in 111 cases. The average survival in these is two years and nine months after operation.

Of the known end-results in these cases, only thirty-one patients, or 19 per cent, have survived five years. It would seem therefore that in general the end-results in men are not so good as in women.

Table 5 gives the details of the forty-one cases in which the patients are still alive. The person who has survived longest was operated on by Dr. Hodge of Philadelphia. This patient is well and apparently free

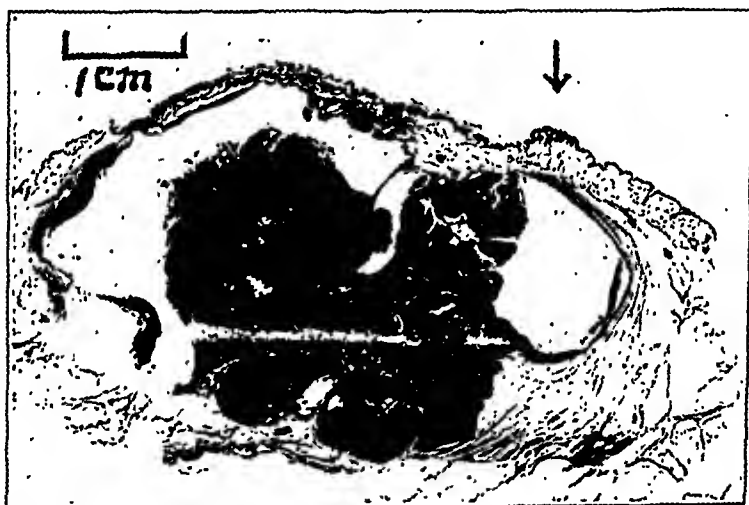


Fig. 2.—Duct papilloma, carcinomatous, in a man, aged 82. Duration of condition was twelve years. He was operated on June, 1926; well February, 1927. Arrow indicates nipple. (Slide presented by Mattas.)

from cancer fifteen years and nine months after operation. The slide has recently been restudied by Eiman of Philadelphia and by me, but as it is faded a good reproduction cannot be made. The condition is unquestionably a carcinoma of the squamous cell type with low malignancy. The second longest survival is that of a patient reported by Hubbard of Boston as apparently free from cancer thirteen years and three months after operation. Unfortunately, a slide of this case is not now available. The microscopic diagnosis was made by the late W. F. Whitney of the Harvard Medical School. Whitney was studying pathologic conditions of the breast with Warren in the 80's, and his opinion in 1913 should be accepted.

second recurrence. The condition was inoperable when the patient was seen by Coley. A nodule was removed, and the section examined by Braxton showed carcinoma. The condition began when the patient was 19.

The youngest patient in the present series whose case was definitely proved was operated on by Deaver (personal communication). The patient first noticed the growth when he was 23 years old. The primary operation was by another surgeon. The growth promptly recurred and Deaver's operation was for the recurrence two years after the onset of the growth. A follow-up record was not made. The tissue, removed by Deaver and examined by Reiman, was found to be carcinomatous. This slide is in the group in my collection now being restudied, and it is undoubtedly a scirrhus carcinoma of high malignancy. The axillary glands were involved. The tumor was not ulcerated.

The case of the oldest man, aged 91, is recorded by Lunn.<sup>12</sup> The duration of the condition is not given, and the patient died after the operation.

#### AGE INCIDENCE

The age of the patient when the tumor was noticed is given in 325 cases; the average age is 52.6 years. In computing this average, cases in which the alleged duration is twenty years or more have been omitted. It is probable in these that the information was incorrect or that a benign tumor became malignant at an unknown date. When the age at which the tumor was noticed is analyzed by age periods, the period of greatest frequency is again from 60 to 64 years. The second most frequent period is from 55 to 59 years. The table according to frequency at age periods is practically the same as table 1, so that the table based on the age when the tumor is noticed need not be repeated.

#### DURATION OF TUMOR BEFORE COMING UNDER OBSERVATION

The time the tumor was observed before coming under the reporter's observation is noted in 342 cases. The average period is 2.4 years. It has been said that men with tumors of the breast delay longer before consulting a physician than women. This study does not show any essential difference: the delay is perhaps greater than with women at present, but many of these cases were reported before the present interest in cancer developed—many before the days of antiseptics.

Table 2 shows that nearly half of the men apply for treatment during the first twelve months. It is doubtful that women equal this even now.

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12. Lunn: *Tr. Path. Soc. London*, 48:247, 1897.

that a microscopic examination was made. Correll of Easton has a patient who is alive ten years after the operation; however, the slide from this case is too faded to be of value.

Table 6 gives details concerning patients who died more than five years after the operation. The case of greatest interest is reported by Mitchell of Washington. A slide of this case is reproduced in fig. 4 and has recently been restudied by Bloodgood and myself. It definitely shows carcinoma. It is of the cylindroma type, and hence in McFarland's classification it falls into the adeno group. The malignancy classification is definitely low. This patient's physician was in

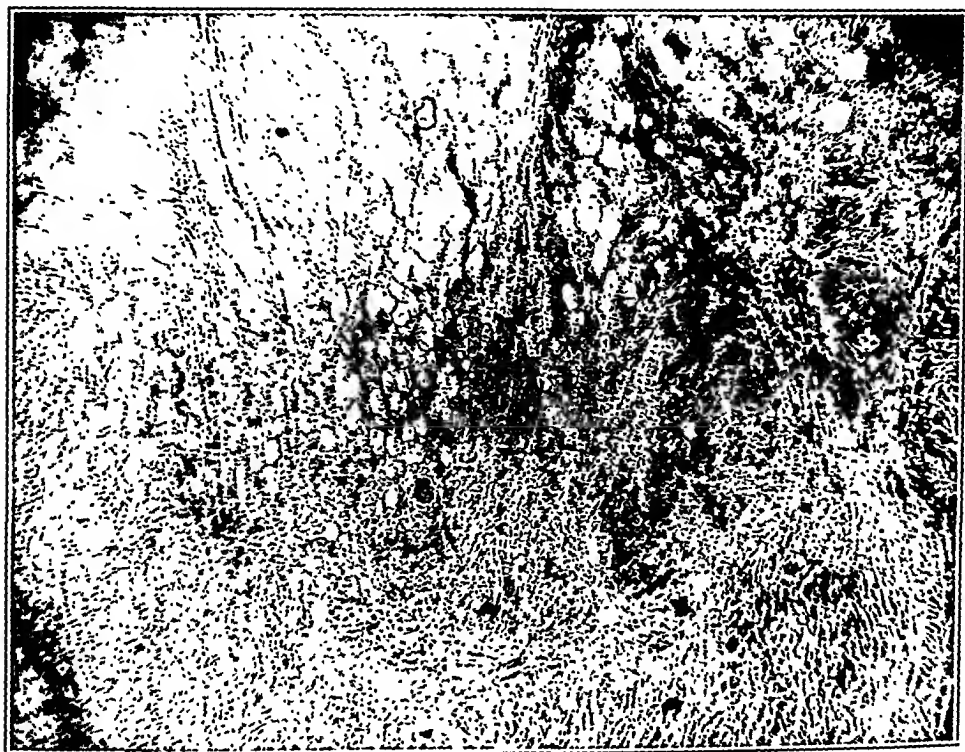


Fig. 4 (Dr. Mitchell's case).—Adenocarcinoma, cylindroma type. The patient had had the condition five weeks; he died twenty-two years after operation of heart disease. He was free from cancer. Same case as figure 5. (Slide lent by Bloodgood.)

close touch with him for many years. He is convinced that the patient remained free from cancer. Death was due to heart disease twenty-two years after operation at the age of 71. This is the longest recorded survival in which data of the case are definite and an unquestionable slide is still available. Figure 5 shows this patient fourteen years after operation. It is remarkable that another slide lent by Bloodgood is almost identical with the slide of Mitchell's case. It is even of lower malignancy. In this case the patient, colored, aged 69, had a tumor of five years' duration. The glands in the axilla were not palpable. The

The only case history that indicates a previous pathologic condition was one of A. C. Wood, Philadelphia (personal communication). The patient, aged 47, had a tumor of unknown duration, said to have developed in a "port wine mark." A microscopic diagnosis showed basal cell carcinoma. The slides are not available now and the end-result is unknown.

#### RACE INCIDENCE \*

Sirrha<sup>13</sup> reports a case in a native East Indian, aged 35, in whom the condition was of two months' duration. The tumor was ulcerated, but the axillary glands are not mentioned. An operation was performed. The end-result and microscopic report are not given. Welch<sup>14</sup> reports a case, his report is accompanied by good photographs and slides. The patient was a Kikuyu, British East Africa, aged 42. The duration of the tumor was two months. It had ulcerated, and the axillary and supra-clavicular glands were involved. An operation was performed. The microscopic diagnosis was adenocarcinoma. The end-results are not given. These are the only two cases found in the literature that did not occur in Caucasians or in American negroes. Numerous cases are reported by American surgeons in negroes. It has been impossible to determine anything in connection with incidence and proportion of white and black populations in the towns represented. The cases are so numerous that presumably the negroes show about the same general incidence as the Caucasians.

#### CHARACTERISTICS OF CARCINOMA OF THE BREAST

*Ulceration.*—Naturally, ulceration of the skin at time of observation is more common in men than in women. This point is mentioned in 306 cases; in these, ulceration was present in 162 patients or more than one-half—a higher figure than one would expect. In the cases in which ulceration is not mentioned it probably did not occur. A comparison with the total number of cases therefore is presumably more correct. Of the total reported in this collection, ulceration is definitely stated to be present in 38 per cent. Ulceration does not seem to follow any law. In some cases it is the first symptom noticed; in other cases, it occurs within a month after the tumor is first noticed. In many cases the

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\* Since this paper was written a report by Ludlow (*China M. J.*, Dec. 1925) has been found. Ludlow's patient was a native Korean, aged 70, with a tumor of seven years' duration which was ulcerated. The axillary glands were not involved; a radical operation was performed. Two years and three months later (September, 1925), the glands were removed from both axillae; no later note. Dr. Ludlow kindly sent on slides from each axilla. They are unquestionably adenocarcinoma of low malignancy.

13. Sirrha: *Indian M. Rec.* 10:146, 1896.

14. Welch: *Lancet*, 1:1319, 1914.



patient died two years and eight months following the operation with enlarged glands in the axilla and internal metastases. It is possible that the difference in result is accounted for by the fact that the axilla was not dissected on account of the age of the patient and the apparent benignity of the tumor.

Study of table 6 shows that in men as well as in women recurrence can be the cause of death well after the fifth year period, as in Finney's and Bloodgood's cases in which recurrence caused death twelve and ten years, respectively, after operation. In both these cases death was possibly delayed by one secondary operation. In the twenty patients surviving five years, the condition at death is indicated in twelve; six were considered free from cancer, and six died of definite recurrence. Probably in one other case (Robert's) the patient died of recurrence.

*End-Result According to Variety of Growth.*—A study of the end-result according to the histologic variety is of considerable interest.



Fig. 5 (Dr. Mitchell's case).—Patient shown fourteen years after operation; lived eight years longer.

Table 9 shows the duration before and after the operation in the cases in which slides have been available for the present study. Ideas as to classification vary so much that it has not seemed profitable to make this analysis for all the cases reported. The present grouping has at least the advantage of having been made by a single observer.

Definite deductions must not be made from this small list of cases. Several interesting points, however, are indicated. The slower growth of the adenocarcinomas seems to be well shown by the decidedly longer time they exist before the surgeon is consulted. There is a similarity as to the time before the operation in other varieties except the gelatinous. There are only three in this group. This small number shows a long duration before operation and a short survival after operation. All three are dead. The duration after operation which is known in two is two years and four months, and ten months, respectively. The medullary, adenocarcinomas and squamous or basal cell



(b) The time elapsing between operation and death shows a fairly regular fall in each group from those with a condition of low malignancy to those with a condition of high malignancy.

(c) The patients still alive after operation show a regular fall in each class from those with a condition of low malignancy to those with a condition of high malignancy. The same is true of the duration of the period of survival after operation in those dead.

(d) Regardless of whether they are dead or still alive, the number of patients passing the five-year period is as follows: low malignancy, 7, or 23 per cent; medium, 5, or 29 per cent; high, 2, or 6 per cent.

(e) The differences in clinical course between the medium and high groups are much more marked than the differences between those of the medium and low groups.

There have been a few cases in which these rules have not applied; that is, some cases in which the condition was classed as being of low

TABLE 8.—*Showing End-Results Classified According to Differentiation (Greenough)*

	Total in Group	Average Duration before Operation	Average Duration after Operation of Cases in Which Patient Is Known to Be Dead	Patients Alive at Present Writing
Low.....	30	2.7 years (22 cases)	5.6 years (10 cases)	13 (43.3%)
Medium.....	17	2.1 years (13 cases)	4.9 years (7 cases)	6 (35.5%)
High.....	29	2.1 years (25 cases)	2.0 years (13 cases)	9 (31.5%)

The patients still alive in the three classes have survived the following number of years:  
Low malignancy.—1.50, 15.33, 1.08, 1.33, 10.00, 0.16, 2.58, 4.25, 5.75, 6.75, 4.16, 3.50, 2.00 years.  
Average, 4.1 years.

Medium malignancy.—1.58, 3.00, 0.50, 3.75, 8.50, 5.00 years. Average, 4.1 years.

High malignancy.—2.50, 3.00, 1.08, 5.00, 0.84, 1.58, 0.25, 5.00, 0.25 years. Average, 2.00 years.

The longest survival recorded (Mitchell's case noted above) in a proved case, is that of a patient who was definitely in the low malignancy group. He lived twenty-two years after the operation and died free from cancer.

malignancy have run a rapid course, and vice versa. However, the impression gained from this study is that it is of great value and that in general one can now fairly accurately indicate the clinical course from the microscopic picture and that even now the information gained from the microscope may be more correct than the clinical observation. For instance, in a case of Bloodgood's the known duration of the tumor was three years. It was "large," the skin was ulcerated, the muscle involved and the highest removed gland was involved. Surely the clinical data could not be worse, yet the malignancy group was low, and the man is alive and apparently free from cancer four years and two months after operation.

The discrepancies that now exist and the objections of some pathologists will probably largely disappear as pathologists more closely compare their slides with end-results.

*The Effect of Muscle Involvement on End-Results.*—This has been an interesting study, especially as from the closer position of the muscle it is involved earlier and more frequently than in women. A priori one

was operated on by Dr. John B. Deaver, the original diagnosis being made by Dr. John Reiman. The slide which was lent for the present study is characteristic. The patient was 57 years old, the duration of tumor before operation was not stated. The classification was low malignancy. The patient died eight years and one month after operation; the cause of death was unknown. A recurrence had not been reported.

The three malignant duct papillomas form an especially interesting group. David<sup>18</sup> reports eleven cases from the literature and one of his own in men. These cases were all apparently benign at the time of operation. Some recurred and were still considered benign. A few cases in men have been reported in the literature as malignant. This type of tumor deserves further study in both sexes. David says that about 10 per cent in both sexes become malignant. It would not be surprising if further study showed that all these tumors were malignant from the start or surely and early became so.

TABLE 4.—*Pathologic Classification of Seventy-Eight Cases of Carcinoma of the Breast in Man*

	Total Number	Percentage
Scirrhus.....	38	49
Medullary.....	14	18
Simplex.....	3	3.7
Adenocarcinoma.....	13*	17
Gelatinous.....	3	3.7
Squamous or basal cell.....	7†	9

\* Includes 3 malignant duct papillomas, 1 comedo type.

† Includes 1 basal cell.

The details in the three present cases so far as known are as follows:

CASE 1.—(Dr. J. P. Hoguet, N. Y., personal communication). A man, aged 57, had a tumor fourteen months before operation. Low malignancy was diagnosed from the section. The patient died four years and seven months after operation. There was a recurrence in the chest.

CASE 2.—(Dr. J. C. Bloodgood, Baltimore, personal communication). The patient, aged 35 at the time of operation, had had the condition for two years. Low malignancy was diagnosed from the section. The patient was well Jan. 25, 1927, one year and eight months after operation.

CASE 3.—(Dr. W. W. Propst, Scranton, Pa., personal communication). The patient, aged 82, had a tumor of twelve years' duration, which grew slowly for the first nine years, then rapidly. The section showed low malignancy. An operation was performed eight months before this article was written. The patient is still well. A photograph of a section of the entire tumor is shown in figure 2.

In all three of these cases the malignancy is definitely shown by marked permeation of epithelial cells in the walls of the cysts and surrounding tissues.

18. David: Ann. Surg. 75:652 (June) 1922

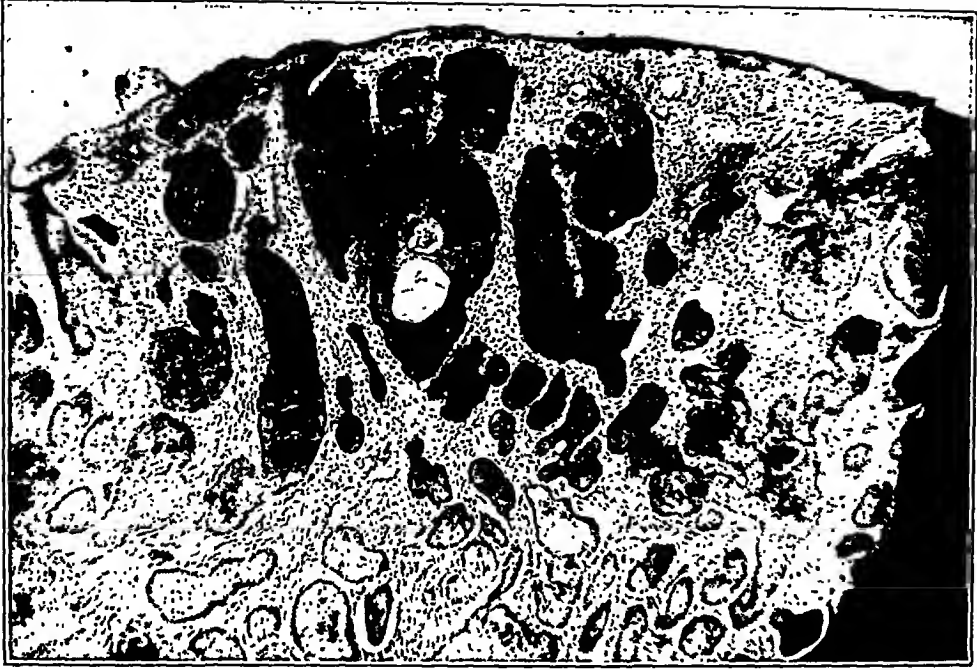


Fig. 8 (Dr. Deaver's case).—Basal cell epithelioma, low malignancy, in a man, aged 57. Duration of condition was unknown. Patient died eight years and one month after operation. (Slide lent by Reiman.)



Fig. 9 (Dr. Jeanneny's case).—Squamous cell carcinoma, low malignancy, in a patient, aged 64. Duration of condition was thirty-four years; patient well and free from cancer two years and two months after operation.

2/3/23	120	Personal com- munication	G.D.C.	57	Ewing	Bloodgood	Shuplex	No	No	Low	9/18/25	9 mos.	2	7	3	4	Yes
2/23/23	Berg	Personal com- munication	J.A.J.	56	Bloodgood	Yes	Yes	Yes	No	Low	1/26/27	1 yr.	3	11	4	11	Yes
3/2/23	Berg	Personal com- munication	C.D.	43	Mandelbaum	Yes	Yes	Yes	No	Low	9/27/26	8 mos.	3	6	4	0	Yes
7/17/23	Quinner	Personal com- munication	S.P.	40	Shaffer	Yes	Yes	Yes	No	Low	2/13/25	Few mos.	1	9	1	9+	No
7/23/23	Capwell	Personal com- munication	M.K.	42	Shaffer	Yes	Yes	Yes	No	Low	1/21/27	5 wks.	3	6	3	7	No
7/23/23	Coyle	Personal com- munication	F.Q.	53	Shaffer	Yes	Yes	Yes	No	Low	1/21/27	5 wks.	3	6	3	7	No
7/23/23	Atchinson	Personal com- munication	A.W.J.	61	Bloodgood	Yes	Yes	Yes	No	Low	1/11/27	1 yr.	2	11	3	11	No
7/23/23	Campana	Personal com- munication	W.P.	53	Clarke	Yes	Yes	Yes	No	High	6/3/26	29 yrs.	2	2	22	2	Yes
7/23/23	Deamant	Personal com- munication	.....	15	Clarke	Yes	Yes	Yes	No	Low	9/15/26	1 yr.	2	1	3	1	No
7/23/23	St John	Personal com- munication	No. 1	61	Sabrazes	Yes	Yes	Yes	No	Low	3/27/28	34 yrs.	2	2	3	1	No
7/23/23	Old	Personal com- munication	F.W.	51	Clarke	Yes	Yes	Yes	No	High	1-28-26	6 wks.	1	15	3	1	Yes
7/23/23	Woolf	Personal com- munication	R.W.S.	58	Bloodgood	Yes	Yes	Yes	No	Low	1/21/27	1 yr.	2	2	2	2	Yes
7/23/23	Speed	Personal com- munication	G.W.	71	?	Yes	Yes	Yes	No	Low	2/1/27	1 yr.	2	6	3	5	Yes
7/23/23	Gold	Surge. Gynec. Obs.	M.P.	..	?	Yes	Yes	Yes	No	High	3/2/26	1 mo.	1	6	1	7	Yes
7/23/23	Walt	Personal com- munication	No. 7	..	?	Yes	Yes	Yes	No	Low	1-28-26	6 wks.	1	15	3	1	No
7/23/23	Bourghon	Personal com- munication	M.R.	35	Ewing	Yes	Yes	Yes	No	High	2/1/27	1 yr.	2	6	3	5	Yes
7/23/23	Sullivan	Personal com- munication	J.A.S.	..	Bloodgood	Yes	Yes	Yes	No	Medium	1925	3 yrs.	1	6	1	7	Yes
7/23/23	Tammann	Personal com- munication	J.H.B.	59	Bourghon	Yes	Yes	Yes	No	High	9/29/25	1 yr.	1	7	1	7	Yes
7/23/23	Park	Personal com- munication	T.A.	71	Ewing	Yes	Yes	Yes	No	Low	1-28-26	6 wks.	1	15	3	1	No
7/23/23	Gold	Personal com- munication	C.M.K.	53	White	Yes	Yes	Yes	No	Medium	2/8/27	9 mos.	1	6	2	3	Yes
7/23/23	Murphy	Surge. Gynec. Obs.	No. 11	48	?	Yes	Yes	Yes	No	High	12/28/25	1 yr.	0	3	1	3	Yes
7/23/23	Prigod	Personal com- munication	P.M.	68	Tillman	Yes	Yes	Yes	No	Medium	1-25-27	6 mos.	1	2	1	8	Yes
7/23/23	Prigod	Personal com- munication	M.H.	52	Mallory	Yes	Yes	Yes	No	Low	1/29/27	1 mo.	0	6	2	6	No
7/23/23	Prigod	Personal com- munication	M.H.	52	Mallory	Yes	Yes	Yes	No	Low	2/15/27	12 yrs.	0	7	12	11	Yes

On Dec. 24, 1927, Dr. Cession writes that this patient died of metastases in mediastinum in October, 1928.  
 On Feb. 6, 1928, Mr. Wood writes that this patient is alive but in bad condition on account of local and mediastinal recurrence.  
 On Dec. 1, 1928, Dr. Wood writes that the patient died of recurrence one year and four months after operation.

Taking the entire group (nineteen cases) with muscle involvement, the average time of the death of the patient is 2.8 years after operation. For 111 cases in the entire series (literature included), this average is 2.9 years. As far as one can judge from this series, involvement of muscle does not seem to shorten the end-result. It does not follow that this applies to women as in women the muscle is usually farther away from the primary tumor and its involvement indicates a wide extension from the original focus. Muscle involvement in women for the present therefore should be accepted as of much graver import than in man.

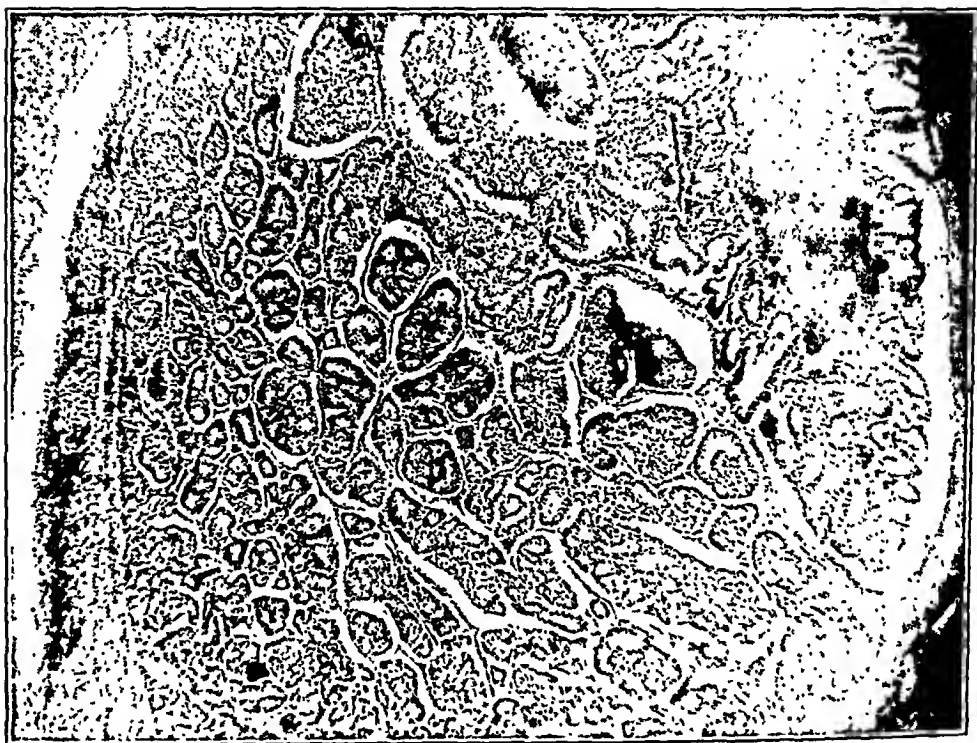


Fig. 11.—Adenoma type of carcinoma, in a patient, aged 88. Duration of condition was one year; patient died two months after operation; acute perforation of gallbladder or duodenum; metastasis? (Slide lent by Bloodgood.)

*Influence of Axillary Involvement on End-Result.*—Accurate data on this point are available in ninety cases. In twenty-one cases in which the axilla was considered not involved the average survival of the patient after operation was 5.2 years. In sixty-nine cases in which the axilla was involved this average was 2.8 years. Reference to tables 7 and 8 shows that even if the axilla is involved there may be a prolonged survival. Hubbard's patient with axilla involved is alive after thirteen years, Deaver's after seven years. Finney and Bloodgood have had

The third longest survival reported by Mackenzie of Auckland, N. Z., is that of a patient apparently free from cancer ten years and six months after operation. A slide of this patient shows that the condition is an adenocarcinoma of the comedo type of low malignancy (fig. 3).

The microscopic section of two of the patients surviving after five years (Wood and Coley) is classified as being of high malignancy. Both of these patients had an unusually long alleged duration before operation, fifteen and six years, respectively. It is probable that in patients with a tumor present so long before operation and surviving a long time after operation there is some factor present that cannot be appreciated with the microscope.

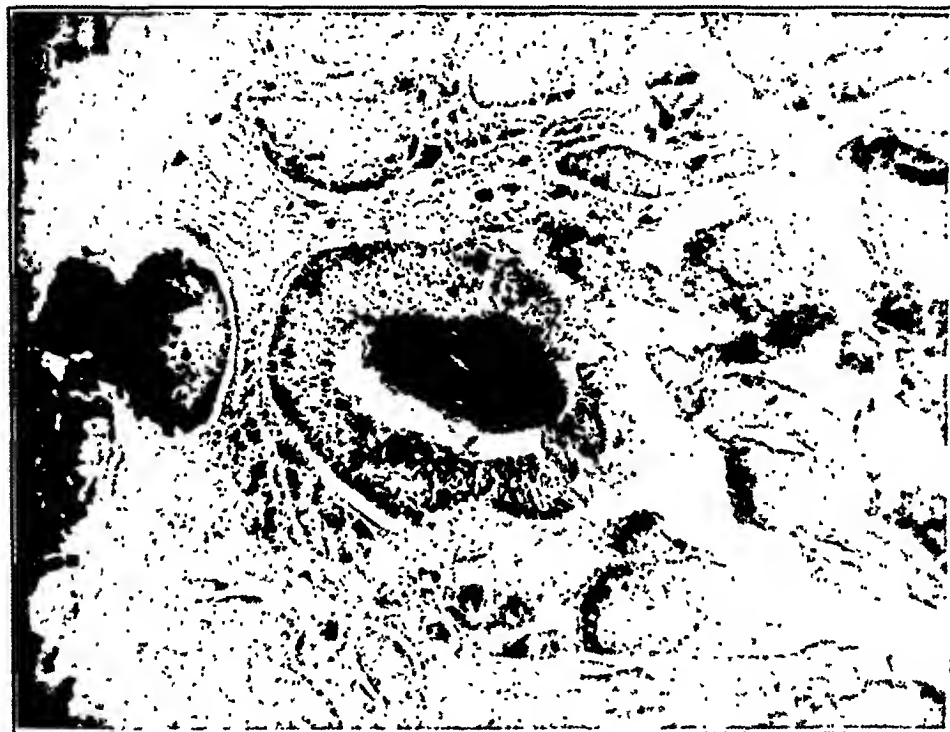


Fig. 3 (Dr. McKenzie's case).—Adenocarcinoma, comedo type, low malignancy. The patient, aged 50, had had the condition for three months, he was well and free from cancer ten years and five months after operation (Slide lent by Bloodgood.)

A few other patients whose tumor was considered carcinoma have been well for a long time, but unfortunately the diagnosis cannot be proved. Willy Meyer operated on a man with a tumor of the breast who is well after twenty years. Neither a slide nor a pathologic report is available. Finsterer<sup>19</sup> mentions a case in a man, aged 24, who was followed twenty years after operation, and then he disappeared from observation. A pathologic report is not given, although Finsterer says

19. Finsterer: *Deutsche Z-schr. f. Chir.* 84:201, 1909.



# RHABDOMYOSARCOMA OF THE VULVAR ORIFICE IN CHILDREN

REPORT OF A CASE

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The great rarity of tumors of the vagina in little girls and the great pathologic interest attached to such tumors have led me to report a case and to review the literature on the subject.

Tumors of the same histologic structure as the one reported in this article have been found in fishes, in mammals and in man. These tumors have arisen from various parts of the body, e. g., from the uvula, the testes, the ovary; the prostate gland and from the muscle fibers in various portions of the body. This article will be limited to rhabdomyomas of malignant character springing from the vagina. This site seems to be the most common point of origin, with the possible exception of the kidney. Holmes<sup>1</sup> compiled thirty-nine cases in 1906. Other less common sites of origin are the heart, lungs, esophagus and uterus.

Since the report of Holmes on thirty-nine cases, Miller and Gurd<sup>2</sup> have reported a case, of which the following is a synopsis:

## REPORT OF CASES

**CASE OF MILLER AND GURD.**—A girl, aged 2 years and 4 months, had as the first symptoms slight straining during defecation and an offensive vaginal discharge. Vaginal examination under anesthesia revealed a greatly dilated vagina filled with friable, gelatinous tumor masses resembling polypi. Radical operation was performed abdominally, the uterus, appendages and dilated vagina being removed. Improvement was only temporary. The tumor recurred with extension to the abdominal cavity in six weeks, and the child died at the end of two months. Necropsy was not performed.

**AUTHOR'S CASE.**—*History.*—H. B., a girl, aged 16 months, at the age of 14 months began to pass polypoid masses, the size and shape of muscat grapes, which the mother discovered on the diaper. Up to this time she was a normal child. The tumors increased in number and were frequently accompanied by blood. The child was taken to the family physician who found a large mass of polypi, similar to nasal polypi, springing from the posterior vaginal wall. These were removed but soon recurred. The child suffered severe hemorrhage, causing profound anemia.

The father and mother and two brothers were well.

In February, 1925, she was referred to me for treatment.

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1. Holmes, O. L. *Pediatrics* 19, 1907.

2. Miller, C. J., and Gurd, F. B.: *Surg. Gynec. Obst.* 11:391-397, 1910.

TABLE 6.—Details of Cases Dying More than Five Years after Operation

Operator	Reference	Case designation	Pathologist	Pathologic Type	Axillary Gland involved	Ulcerated	Malignancy Classification	Duration before Operation	Duration after Operation	Total Time Onset to Death	Slide Examined and Proved in Present Study	Note at Death
Mitchell	Personal communication	G.S.H. 19	Bloodgood	Adenocarcinoma?	No	No	Low	5 weeks	22 years	22 years	Yes	Heart disease; cancer free
Ballock	Wash. M. Ann. 7: 24, 1903	H.M. 66	Graham	Medullary	No	No	?	3 years	16 years	19 years	No	Cancer free
Gillison	Ann. Surg. 50: 171, 1912	G.W. 62	Wood	Adenocarcinoma?	Yes	No	Medium	4 mos.	11 years	11 years	Yes	Details unknown
Fluency	Personal communication	R.J. 18	Bloodgood	Medullary	Yes	No	?	0 mos.	12 years	12 years	No	Recurrence
Bloodgood	Deutsche Ztschr. f. Chir. 84: 201, 1904	V. 57	?	Adenocarcinoma?	Yes	No	Low	2 years	11 years	13 years	No	Nephritis; cancer free
Beaver	Personal communication	F.F. 67	Rehman	Adenocarcinoma?	?	?	?	3 years	13 years	13 years	Yes	Recurrence
Pollock	Personal communication	J.T. 67	Bloodgood	Medullary	Yes	Yes	?	?	9 years	12 years	No	Heart disease; cancer free
Fluency	Tr. Path. Soc. Lond. 27: 221	65	?	Adenocarcinoma?	Yes	No	Low	1 year, 6 mos.	9 years	9 years	No	Apoplexy; cancer free
Graham	Personal communication	H.B. 60	McFarland	Simplex	No	No	?	10 years	8 years, 9 mos.	8 years, 9 mos.	No	Carcinoma of throat
Timberlake	Personal communication	N.E. 67	Rehman	?	Yes	No	Low	?	7 years, 7 mos.	7 years, 7 mos.	No	Recurrence
Robertson	Personal communication	W.S.S. 60	?	Basal cell	Yes	Yes	?	?	9 years	9 years	No	Heart disease; cancer free
Ambl	Personal communication	J.K. 62	Wood-Lewis	?	No	No	Low	1 year, 6 mos.	8 years, 3 mos.	8 years, 3 mos.	No	Apoplexy; cancer free
Wood-Lewis	Surg. Gynec. Obst. 42: 15, 1903	J.T.H. 60	?	Simplex	Yes	No	?	10 years	8 years, 1 mo.	8 years, 1 mo.	Yes	Details unknown
Fluency	Personal communication	No. 10	?	?	Yes	No	?	?	7 years, 7 mos.	7 years, 7 mos.	No	Recurrence
Fluency	Deutsche Ztschr. f. Chir. 84: 201, 1904	J.H. 62	?	?	?	?	?	?	6 years	6 years	No	Cause (?) Ind. obstinate
Graham	Personal communication	No. 8	?	?	Yes	High	?	?	5 years, 6 mos.	5 years, 6 mos.	No	Nephritis for 2 years
Beaver	Personal communication	M.C.S. 53	Selfridge	?	Yes	?	?	?	7 years, 7 mos.	7 years, 7 mos.	No	Details unknown
Beaver	Personal communication	W.S. 75	?	?	No	?	?	?	5 years, 5 mos.	5 years, 5 mos.	No	Details unknown
Beaver	Personal communication	No. 1	?	?	No	?	?	?	3 years, 3 mos.	3 years, 3 mos.	Yes	Recurrence
Beaver	Personal communication	W.G. 10	Selfridge	?	No	Medium	1 year, 6 mos.	5 years	3 years, 3 mos.	3 years, 3 mos.	No	Recurrence

\* The term cancer has appeared the last available clinical data. Cases were rarely under the care of the reporter at the time of death. An autopsy is recorded in only one case (H.M. 66).

tumor mass was white and slightly lobulated. One portion on the surface was necrotic. On section the pedunculated tumors resembled a mucous polyp. On section the largest part of the tumor was firm and white, and a clear serum oozed from the cut surface. It was slightly fibrous. Grossly, the diagnosis was multiple polypi springing from a large mass, which, grossly, was a fibronyoma.

The histologic diagnosis was endothelioma, or spindle cell sarcoma (malignant).



Fig. 2.—Appearance of child a few days before death.

The child remained well until Nov. 11, 1925—more than nine months—when she again passed two or three small polypi. These were removed and an additional 300 mg. hours of radium was given. In about two weeks the child began to fail. There was no return of the tumor at the original site, but the abdomen began to fill, and the patient gradually became emaciated. Jan. 27, 1926, the abdomen had become enormously distended; coursing over it were

variety show the longest survival after operation and are surprisingly similar. The scirrhus type, as is to be expected, shows a short survival after operation. It is probable that the simplex variety would show a longer survival if there were more cases.

*End-Result According to Differentiation (Greenough<sup>20</sup>).—*Prolonged study has been given to the end-result in connection with the degree of differentiation as described by Greenough.

The sections from the seventy-nine cases studied have been grouped as to differentiation into three groups; high, medium and low malignancy. This study has lead me to agree with Greenough that it is best not to attempt to differentiate more than three classes. This is partly because I do not feel that I can divide my cases into four classes and partly because I feel that the division into four groups is finer than the traffic will bear. In actual practice one puts a section in the middle because one does not know in which end it should be put. Why split up a middle class thus formed?

TABLE 7.—*Showing End-Results Classified According to Variety of Growth*

	Total In Group	Average Duration Before Operation	Average Duration at Death After Operation	Alive at Present Writing
Scirrhus.....	35	1.7 years (26 cases)	2.4 years (18 cases)	6
Medullary.....	14	1.2 years (8 cases)	7.1 years (6 cases)	6
Simplex.....	3	2.2 years (3 cases)	1.9 years (1 case)	2
Adenocarcinoma.....	13	4.5 years (11 cases)	7.1 years (5 cases)	5
Gelatinous.....	3	3.2 years (3 cases)	1.5 years (2 cases)	0
Squamous or basal cell.....	7	1.5 years	7.2 years (4 cases)	2

Dr. A. P. Stout, of Columbia University, has also studied my collection of slides from this standpoint, and we have agreed as to the grade of malignancy in most cases. Where there has been a difference of opinion, Stout's classification has been accepted.

The number of cases of carcinoma in men studied in this group is almost equal to the number studied in Greenough's group of women. It is striking that in both groups the number of cases in each assigned to the low and high malignancy classes is practically equal, namely, for men, 30 low and 29 high; for women, 19 low and 21 high. There is a considerable difference in the proportion assigned to the medium group. In men 22 per cent were in the medium group, in women 45 per cent were in the medium group.

A study of table 8 shows that for this group of men the following points seem to be indicated:

(a) A difference is not shown in the groups as to the known duration of the tumor before operation.

<sup>20</sup> Greenough: *J. Cancer Research*, 9:453 (Dec.), 1925.

many accessory, distended veins (figs. 2 and 3). The lower part of the abdomen was flat on percussion, and ballottement was present. The upper part of the abdomen was tympanitic. The abdomen was tapped at this time with a large trocar and 100 cc. of bloody fluid evacuated. February 7, one year after my first examination, the baby died of toxemia and exhaustion.

*Postmortem Examination.*—Dr. B. F. Sturdivant, pathologist to the Pasadena Hospital, reported that the body, that of a small child, was greatly emaciated. The length was 91 cm., and the circumference of the abdomen 78 cm. The ensiform to the navel measured 23 cm., to the pubes 30 cm. There was marked edema of both legs.

The veins of the abdomen had ruptured from pressure. The tumor mass filled the entire abdomen, and had pushed the intestines up high against the diaphragm. The pericardial sac was filled with fluid. Tumor masses were

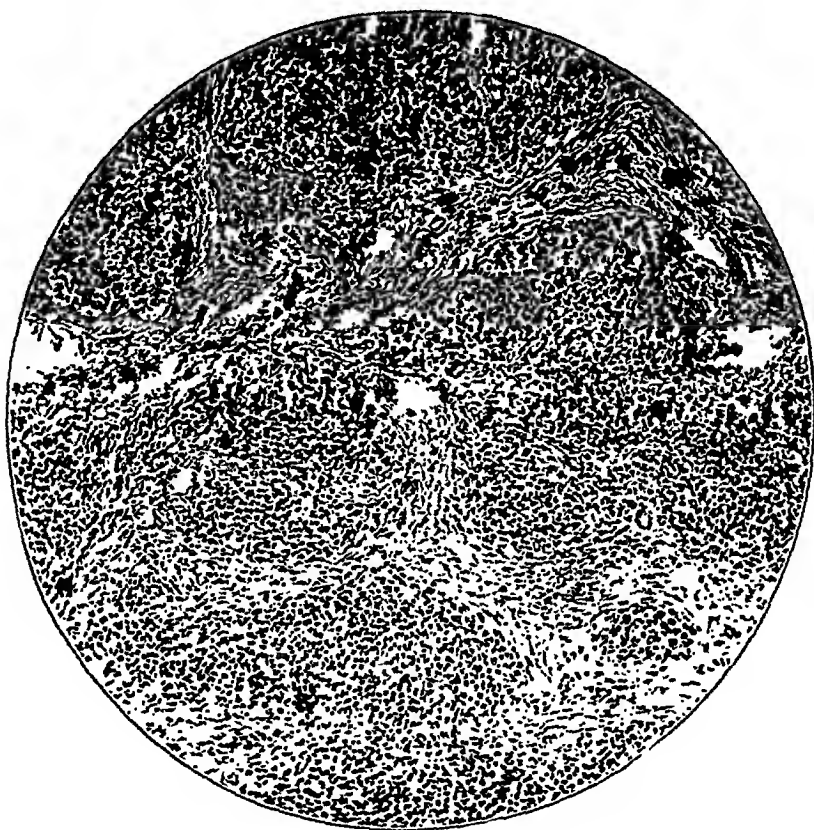


Fig. 5.—Spindle cells forming wide strands.

present on the pericardium. The tumor had broken through the pelvis retroperitoneally, along the vessels. There were many pigmented areas with hemorrhage into them.

The bladder contained a group of tumor masses similar to those in the vagina and in the abdomen. The uterus and vagina were normal. The ovaries were not identified. The liver, gallbladder and spleen were normal. There were one or two tumor masses on the under surface of the diaphragm. The right kidney was dilated and hydronephrotic. There were no tumor masses in the kidneys. The left kidney was normal in size; there was slight dilatation of the pelvis. There were a few tumor masses on the upper surface of the diaphragm, and a few in the retroperitoneal glands. A small tumor mass was

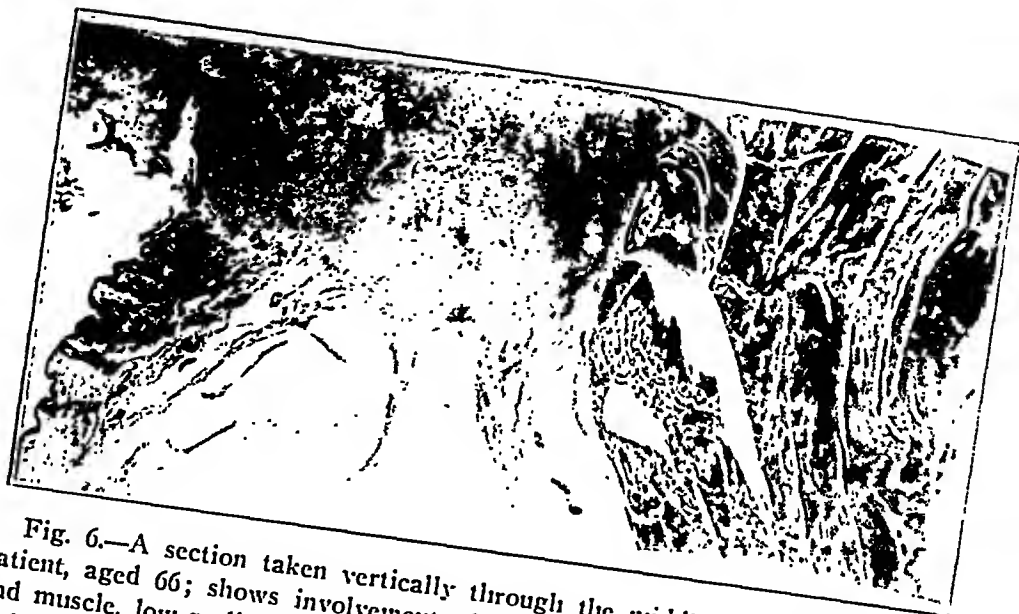


Fig. 6.—A section taken vertically through the middle of the nipple, in a patient, aged 66; shows involvement of the nipple, nearby skin, entire breast and muscle, low malignancy. Duration of condition three years; patient well and free from cancer four years and two months after operation. (Slide lent by Bloodgood.)

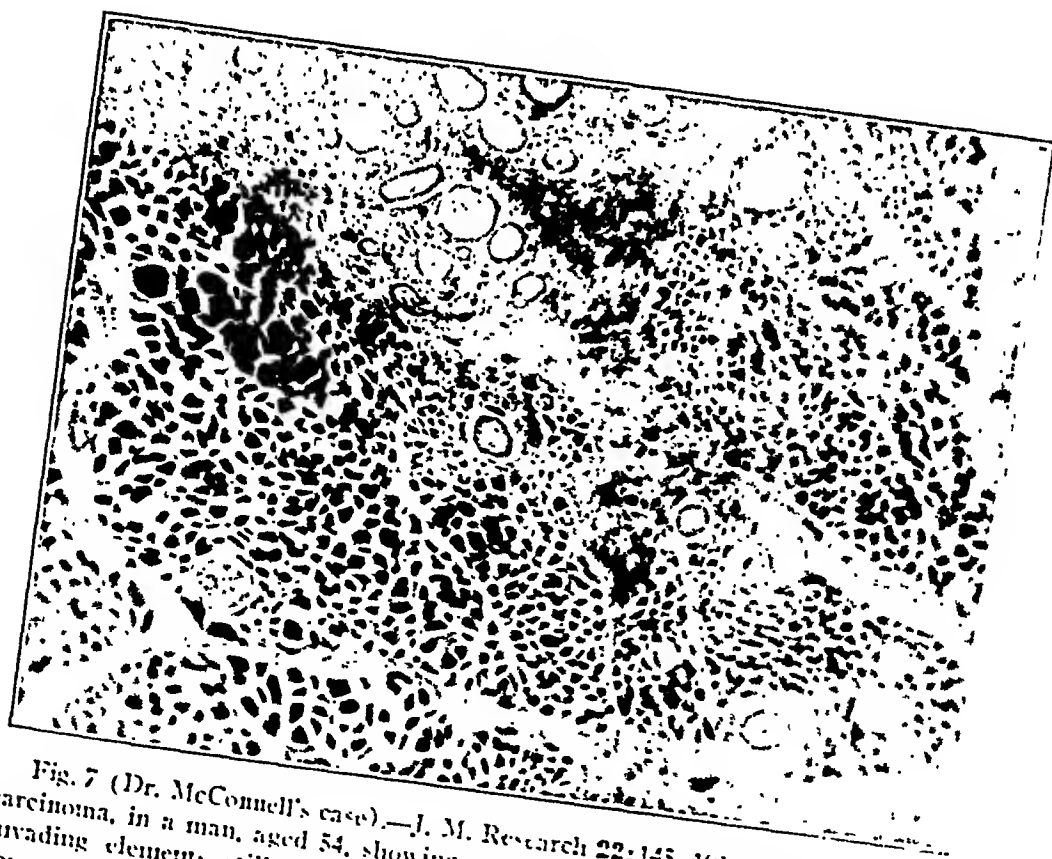


Fig. 7 (Dr. McConnell's case).—J. M. Research 22:145, 1910. Tubular type of carcinoma, in a man, aged 54, showing marked involvement of the total nipple. Invading elements still maintain complete tubular structure. All the nodes covered at autopsy. (Slide lent by McFarland.)

developed striated muscle elements, does not spring from fully developed muscle fibers, but arises from embryonic cells which are capable of giving rise to striated muscle in the process of development.

The great malignancy of these tumors would suggest their origin from cells of the embryonic type which have undergone little differentiation. Sarcomas vary in their malignancy in proportion to their amount of connective tissue. Connective tissue tumors in which the cells are capable of producing a large amount of fibrous tissue are less malignant than those in which small spindle cells or round cells predominate. Metastasis is not common in the rhabdomyosarcomas either by the lymphatics or blood stream, but they extend rapidly by continuity. In my case, however, there was metastasis to the lungs.

The literature on this subject shows that these tumors are characterized, first, clinically thus: (a) Early symptoms and a period of slow growth, during which there is an apparently benign proliferation of tissue from the vaginal wall, are absent. (b) At the vulvar orifice appear tumor masses, polypoid in character, associated with more or less severe hemorrhage, which is often the first symptom and which may vary from a mere stain to copious bleeding. (c) Pressure is felt in the bladder and rectum from the growth in the vagina. The tumor may attain a large size and enormously dilate the vagina before appearing at the orifice. The bladder symptoms in my case were so pronounced that the tumor was thought to be a bladder tumor by one of the surgeons who saw it. There was distention of the bladder with incontinence. (d) Inflammatory changes appear on the surface of the growth, with sepsis. Urine escaping from the distended bladder seeps into the distended vagina, where it decomposes and sets up an inflammatory process, resulting in a foul smelling, bloody discharge. Owing to the small vulvar orifice, drainage is poor. (e) Extension of the tumor takes place by continuity rather than by metastasis. In my case, there was late metastasis to the lungs. The tumor progressed by extension through the vaginal vault into the abdominal cavity. The entire abdomen became enormously distended with polypoid masses. When the diaphragm was reached, the tumor metastasized to the lungs, probably through the blood stream. There was no involvement of the rectum or vagina. The child became greatly emaciated and died of sepsis and inanition.

Second, histologically these tumors are characterized by (a) a vascular connective tissue framework, (b) imperfectly developed striated muscle—the muscle tissue never attains the full development of mature striated muscle<sup>2</sup>—and (c) cells showing transverse striations or

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3. Hektoen, Ludvig, and Reisman, David: American Textbook of Pathology, Philadelphia. W. B. Saunders Company, 1901.

would infer that involvement of the muscle would greatly diminish the chance for long survival. Every physician now accepts it as a definite fact that massage rapidly spreads a primary growth. This could not be done better than by the continuous movement of a muscle on epithelial cells which have invaded its fibers. This is probably what led Heidenhain<sup>21</sup> many years ago to write that when a muscle is once involved, probably the whole muscle will be affected, and it should be removed entire, including the periosteum at its attachments.

In the group of seventy-nine cases in which slides were available for study, there was definite microscopic evidence of involvement of the underlying muscle in nineteen cases, 24 per cent.



Fig. 10 (Moschowitz's case).—Carcinoma apparently arising at the mouth of the duct, deeper tissues show a medullary type, low malignancy, in a patient aged 67. Duration of condition was ten years, two recurrences removed in first years, then patient disappeared from observation. (Slide lent by Max Liebaum.)

In cases in which the muscle was involved, the classification of the primary tumor is as follows: low 6, medium 3, high 10. The proportion of these cases in the high malignancy class is greater than in the entire group as 52 is to 38. The average time of death after operation for the low and medium classes combined is 3.3, for the high 2.2 years. There is one patient alive in each group after five years.

21. Heidenhain: *Ann. Surg.* 10:583, 1891.



# CIRCUMINJECTION OF AUTOGENOUS BLOOD IN THE TREATMENT OF CARBUNCLES

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NEW YORK

The purpose of this article is to present the results of the application of a method of defense against the spread of infection in a carbuncle. Carbuncles have been treated by such methods as hyperemia, injection of antiseptics into their centers, ointments, vaccines, roentgen-ray therapy, and conservative and radical surgery, but extensive scarring, lengthy convalescence and the frequency of complicating sepsis or metastatic pus foci accompanying these methods warrant a consideration of any method that may prevent these conditions. To aid healing and to preclude as far as possible the occurrence of septic complications, two factors are essential, first, the least possible trauma to tissue, and, second, the mobilization of the natural forces of defense.

Within the last eighteen years attempts have been made to use whole blood or its constituents locally to combat infection. In 1908, Mueller and Peiser<sup>1</sup> injected the patient's defibrinated blood into nonprogressive pyogenic abscesses. They thought that the proteolytic ferments of the polymorphonuclear leukocytes caused a rapid purulent secretion by digestion. This secretion helped dilute the toxic products and thus delayed their absorption. Lorey,<sup>2</sup> in 1912, used local applications of horse or diphtheria serum in various pyogenic infections complicating diphtheria or scarlet fever. Thus, when a cervical adenitis in scarlet fever was incised and drained with a packing impregnated with horse serum, he said that less sloughing and toxicity resulted and clean granulations appeared early.

Ten years later, in 1922, Rieder<sup>3</sup> sought a method for the treatment of carbuncles and furuncles which would prevent unnecessary injury to tissue and the opening up of new avenues of infection. He observed that if a carbuncle or furuncle was incised crucially without undermining the flaps, the insertion of a packing saturated with horse serum or diphtheria antitoxin made the slough begin to separate in twenty-four hours, and in several days bright red granulations appeared in the bottom

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\* From the Presbyterian Hospital and the Columbia University College of Physicians and Surgeons.

1. Mueller, E., and Peiser, A.: Ueber die Technik der Antifermentbehandlung eitriger Prozesse. *Beitr. z. klin. Chir.* 60:236, 1908.

2. Lorey: Neue Gesichtspunkte zur Behandlung der Diphtherie, des Scharlachs und von eitrigen Prozessen. *Med. Klin.* 8:1069 (June 30) 1912.

3. Rieder, Wilhelm: Ueber Behandlung der Staphyloomykosen mittels Pferdserums. *Klin. Wchnschr.* 1:2333 (Nov. 18) 1922.

patients with involvement of the axilla who have died over ten years after operation with recurrence. Finsterer had a patient who died eleven years after operation and who was considered free from cancer.

*Influence of Ulceration on End-Result.*—Accurate data on this point are available in ninety cases. In forty cases in which ulceration did not occur the average survival of the patient was 4.9 years after operation, and in forty cases in which ulceration occurred the average was 2.4 years. From tables 7 and 8 it would seem that ulceration is more of a factor in connection with prolonged survival than is axillary involvement. In only one case in which ulceration occurred (Bloodgood's) did the patient survive operation ten years, and only seven of these patients have survived five years.

NOTE.—I intend to continue this study of carcinoma in the male breast and would be much indebted if surgeons would furnish reports and slides of other cases whether operation has already been performed, or future cases.

bilities and that it would be of value to ascertain whether the spread of infection in a carbuncle could be overcome by this method. If this could be proved in a carbuncle, the use of this therapeutic principle might be of value to check other accessible spreading infections or to minimize the danger of sepsis or purulent metastases. It will be noted that the various authors quoted, in addition to the injection of blood, also incised the carbuncles. No statement is made whether any other aids, such as local heat, antiseptics, ointments or narcotics, were used. Accordingly, it seemed most important to rule out with reasonable certainty the influence of any factors other than autogenous blood circum-injection which might prevent spread of infection, cause sloughing and discharge, alleviate pain and minimize constitutional symptoms. With this in mind, twelve patients who had carbuncles were treated at the Presbyterian Hospital with circuminjection of autogenous blood without other operative procedure under the following conditions:

1. The patients were all nondiabetic.
2. The carbuncles were real and progressive and several colleagues agreed that ordinarily their choice of treatment would be radical surgery. If there was one opinion that a carbuncle might get well with conservative treatment, such as local heat or ointments, that case was not included in the series. In this way at least twenty cases were excluded.
3. Circuminjection of autogenous blood without incision was the only treatment. This method, so far as I know, has not been attempted before.
4. Ambulatory treatment after injection consisted in:
  - (a) Simple dry dressings.
  - (b) Abstention from narcotics.
  - (c) The ordinary measures against constitutional symptoms, such as forcing fluids and limited diet.
  - (d) Wiping away frank pus, removing separated slough, and keeping the surrounding skin clean.

#### TECHNIC

The infected area is prepared in the usual manner and the patient anesthetized, preferably with gas and oxygen or ethyl chloride inhalation. The method was tried without anesthesia in two patients who had small carbuncles, but the procedure was too painful. An assistant withdraws blood from the median basilic vein into a 20 cc. syringe. The operator immediately attaches another needle to the syringe and begins the injections just beyond the margin of induration of the carbuncle. The needle is pushed into the skin and an intracutaneous and subcutaneous injection is begun under considerable pressure. Gradually, the needle is pushed perpendicularly deeper and deeper until little pressure is required to force in the blood. At this point the needle has probably penetrated deep enough for the blood to extravasate through the deep necrotic tissue. The needle is then withdrawn. The same procedure is followed until the lesion has been circuminjected, a sterile needle being used for each injection. It is advisable to allow some blood to well up through the center of the carbuncle. The tissues about the carbuncle are seen to swell up because of the injected blood, and a few drops of blood may exude from the punctures. The number of punctures necessary, perhaps from three

*Physical Examination.*—The child was well nourished, but of pasty complexion. The teeth were poor; the throat was normal. The chest, heart, lungs and abdomen were normal. A pedunculated tumor mass, the size of a small orange, which bled easily when irritated, protruded from the vagina. It seemed attached by a rather broad base to the posterior raphe of the vagina. Over its upper surface, many polypoid tumors resembling a cluster of grapes were found (fig. 1). There was a seropurulent, foul smelling discharge.



FIG. 1. Tumor at time of operation.

*Treatment.*—The tumor was thoroughly removed down to the posterior raphe with the actual cautery. Four hundred milligramm. doses of radium were given. 2 mm. of lead and 1 mm. of brass was given. The child recovered in good health and normal weight.

*Post-operative.*—The removed tumor mass was the size of a small orange, 7 long by 5 cm. wide by 2.5 cm. thick. It consisted of a firm, fleshy mass made up of dark red polypoid nodules, each about 1 mm. in diameter, attached to a common pedicle. The largest of these was located at the posterior raphe.

TABLE 1.—Data in Case 1

TABLE 1.—Data in Case 1												
Before Injection												
Age	Sex*	Location	Duration	Amount of Pain	Temperature†	Size of Indurated Area	Size of Opening	Tenderness	Induration	Echymosis	Violaceous Color	Time for Complete Closure 12 days
Day		Back of neck	5 days	Moderate	100.2	7 by 7 cm.	2 by 2 cm.	Moderate	Present	0	0	
1	♂	Pain	Stiffness	Discharge								
1		Less on twisting neck; slept 6 hours	Present	Moderate; thick yellow slough in center				Moderate	Present	0	Present, 1.5 cm. away from central necrotic area	
2		Slight pain on twisting neck to extreme	Slight	3 cc. thick pus; central slough removed				Very slight	Present	0	Present	
3		No pain on twisting neck	Slight	2 cc. pus and slough; 1 cc. fluid pus expressed				Very slight	Present	0	Present	
4		No pain	0	0.5 cc. thick yellowish pus; slough 1 cc. in diameter; granulations, bright red				0	Beginning to disappear	0	Present	
5		No pain	0	Few drops; central granulating area 1 cc. in diameter				0	Moderate	0	Present	
6		0	0	Slight, serous; pin-sized opening				0	0	0	Present	
7		0	0	Wound practically healed				0	0	0	Beginning to disappear	
8		0	0	Wound healed				0	0	0	0	
10		0	0	0				0	0	0	0	
12		0	0	0				0	0	0	0	

much mixed infection, or it was not considered fair to take culture.

\* In this and the following tables, ♂ indicates male, ♀, female.

† Month.

‡ When cultures were not taken, no pus exuded or could be expressed, or there was too much mixed infection, or it was not considered fair to take cultures of the wound after treatment. However, it is known that most earbunches have Staphylococcus aureus as the infecting agent.

§ Site of injections with reference to numbers on face of clock.

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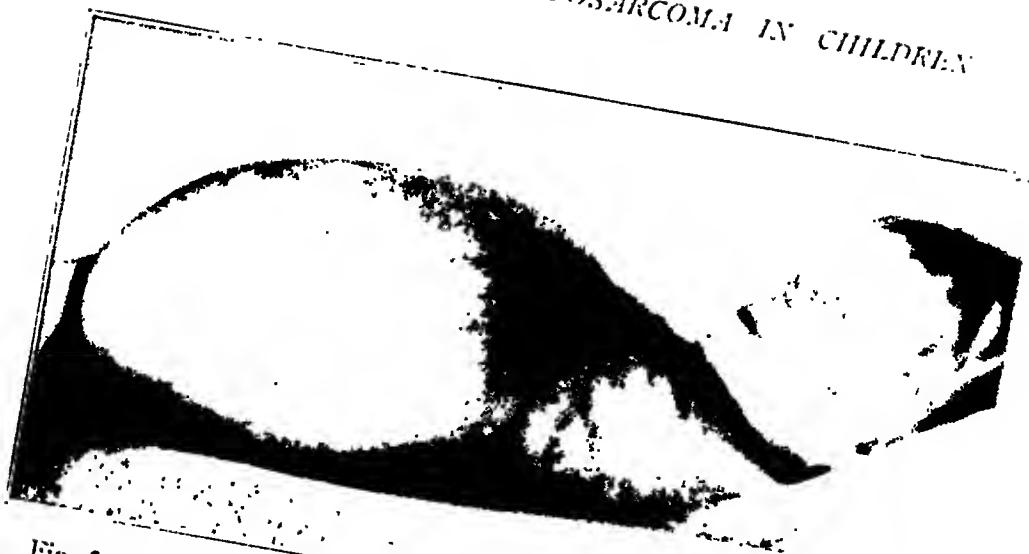


Fig. 3.—Appearance of child in recumbent position; the distended abdominal veins should be noted.



Fig. 4.—Spindle-shaped cells, most characteristic of rhabdomyosarcoma.

TABLE 4.—Data in Case 4

## Before Injection

Age	Sex	Location Back of neck	Temperature	Duration in days	Amount of Pain Moderately severe, especially in right shoulder	Temperature 99.6	Induration 8 by 7 cm.; spreading by 4 o'clock	Size of Opening 11 small open- ings over area 3 by 2 cm.	Tenderness Moderate	Culture Not done	Amount of blood injected 50 cc. at 9, 1, 4, 4 and 7 o'clock
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## After Injection

Day	Pain	Temper- ature	Chill	Stiffness	Discharge	Induration Merging with blood in- jection	Injected Area			Time for Complete Closure 13 days	Scar Minimal
							Tenderness	Induration	Keelymosis	Violaceous	Color
1	Slept well; turned neck easily; felt well; pain in right shoulder gone	98.8	0	0	2 cc. pus	Very slight	Practically none	Slight	0	0	Follow-up, 23 months; scar, 1.5 by 1.5 cm.; extremely superficial, white, cigarette-paper like; not adherent to underlying struc- tures; no induration
2	No pain on turn- ing neck; left thigh; slept well	97.1	0	0	2 cc. thick yellowish pus; necrotic area 1.5 cm. in diameter	0	0	Slight	0	0	
3	None; slept well	98.8	0	Slight	1 cc. thick pus; slough separating; central necrotic area 2 cm. in diameter	0	0	Slight	0	0	
4	None; felt fine	97	0	0	2 cc. pus; 2 small sloughs removed	Merged with blood in- jection	0	Slight	0	0	
5	0	98	0	0	Slight slough on dressing	0	0	Slight	0	0	
6	0	98	0	0	No more slough; cen- tral area 1 cm. in diameter closing in	0	0	Very slight	0	0	
7	0	98	0	0	Slight, serous	0	0	Very slight	0	Violaceous area about granulat- ing area Present	
8	0	98	0	0	0; granulating area 1 cm. in diameter	0	0	0	0	Present, 2 cm.	
9	0	98.8	0	0	Granulations bright red	0	0	0	0	Present	
10	0	98.2	0	0	0; crusted area 1 cm.	0	0	0	0	Present, 2 cm.	
11	0	97.8	0	0	Wound almost healed	0	0	0	0	Present, 1.5 cm.	
12	0	98	0	0	Wound healed	0	0	0	0		

present in the lower lobe of the left lung. The main tumor mass was grayish white and gelatinous.

*Microscopic Examination.*—The sections showed a soft, edematous tumor, having the appearance of a myxoma. Scattered throughout the tumor, and especially around the blood vessels, were numerous spindle-shaped cells, which made a considerable part of the tumor. In places these spindle cells were gathered together forming wide strands. These spindle cells closely resembled muscle fibers, which showed a great many transitional forms. In some of the sections stained with phosphotungstic acid hematoxylin, a few cells with delicate cross striation could be made out. Longitudinal striation could be easily made out in a number of cells. The tumor was vascular. Rarely, a large cell with a mitotic nucleus was seen (figs. 4, 5 and 6).

The diagnosis was rhabdomyoma (sarcoma botryoides, Pfannenstiel).

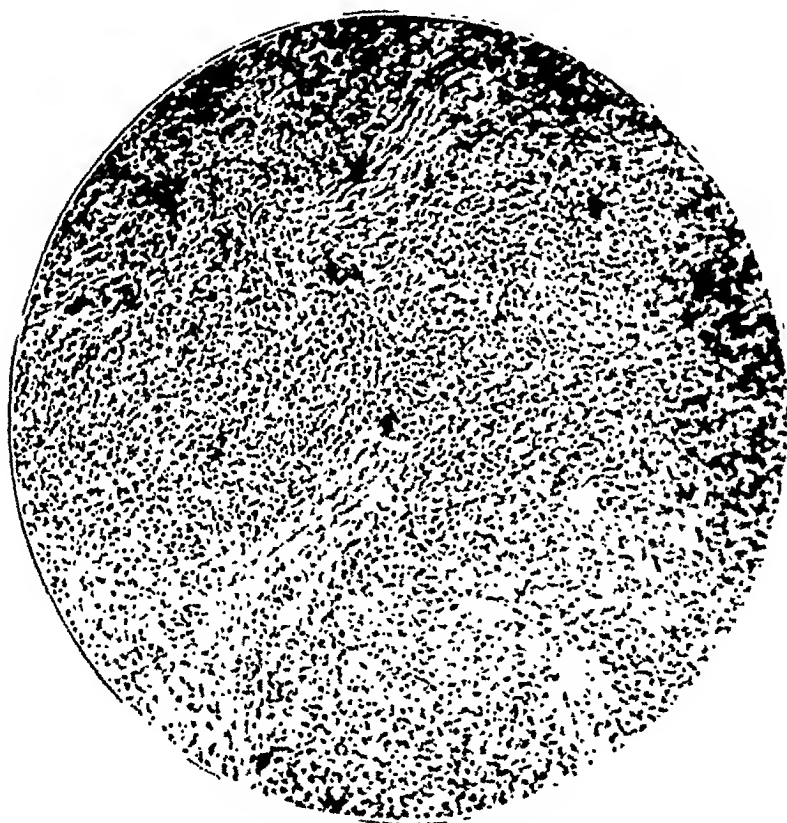


Fig. 6. Cells showing longitudinal and transverse striations.

#### COMMENT



TABLE 6.—*Data in Case 6*

TABLE 6.—Data in Case 6																				
Before Injection																				
Age	Sex	Location	Duration	Amount of Pain	Temperature	Size of Indurated Area	Size of Opening Pin-head	Tenderness	Culture	Amount of Blood Injected	Scar									
												Back of neck	3 weeks	Severe; sleepless nights	99	6 by 4 cm.	Slight	Not done	10 cc. at 8, 12 and 4 o'clock (no anesthesia)	Minimal
After Injection																				
Injected Area																				
Ecchymosis																				
Violaceous Color																				
Color																				
21 days																				
Time for Complete Closure																				
Scar																				
Minimal																				
21 months; scar, 1 by 0.5 cm.; depressed 2 mm. in natural cause of neck; not adherent to underlying structures; no induration																				
Day	Pain	Temperature	Chill	Stiffness	Discharge	Induration	Tenderness	Induration	Ecchymosis	Violaceous Color	Scar									
1	0; stopped 1 hour after injection	98.8	0	0	Slough separating	Less	Slight	Slight	0	0	Follow-up, 21 months; scar, 1 by 0.5 cm.; depressed 2 mm. in natural cause of neck; not adherent to underlying structures; no induration									
2	"	97.5	0	0	2 cc. pus	Less	Slight	Slight	0	0										
3	0	....	0	0	1 cc. pus	0	Slight	Slight	0	0										
5	0	....	0	0	0.5 cc.	0	0	Slight	0	0										
8	"	0	0	0	1 cc.	0	0	0	0	Slight										
10	"	0	0	0	Few drops	0	0	0	0	0										
21	"	0	0	0	Healed	0	0	0	0	0										

Time for  
Complete  
Closure  
21 days

Scar  
Minimal

Follow-up, 21 months;  
scar, 1 by 0.5 cm.; de-  
pressed 2 mm. in nat-  
ural  
crease of neck; not  
adherent to underly-  
ing structures; no  
induration

beadings. It is generally conceded that these tumors are of embryonic origin. The frequency of their occurrence in infants, their location in regions involved in embryonic infoldings, such as Muller's duct, and the embryonal nature of their essential cells, all point to the reasonableness of this theory.<sup>4</sup>

#### TREATMENT

These tumors occurring in the genito-urinary tract are almost invariably fatal, there being only one or two reported recoveries. Theoretically, they should be amenable to treatment if recognized early. The local nature of the growth in its incipency, the rather prolonged period of slow growth and relative benignancy, and the tendency to progress by extension rather than by metastasis, all suggest the possibility of radical cure if the growth is recognized early and treated vigorously. Although she came under observation late and when near death, my patient was restored to perfect health by thorough cauterization and vigorous radium treatment. If given in the early stages, this method of treatment should offer hope of permanent relief.

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4. Hektoen (footnote 3, p. 181).

TABLE 8.—Data in Case 8

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Age	Sex	Location	Amount of Pain	Duration	Discharge	Before Injection			Tenderness	Culture	Amount of Blood Injected 25 cc. at 12, 9, 7, 5 and 3 o'clock																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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17	♂	back of neck	Severe; no sleep 3 nights; fever, chills, headache	One week; induced 3 and 2 days before	1 cc. of thick pus	99.6	4 by 1 cm.	2 by 2 cm.	Marked	Not done																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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of the wound. This result was not obtained by using antiseptics in the same manner. He reported favorable results in sixteen carbuncles and five large furuncles. After the injection of 1 cc. of horse serum into the centers of furuncles, sloughing and healing followed. In 1923, reporting twenty-three cases of carbuncle, some with doubtful progress, Rieder<sup>4</sup> called attention to the same treatment, but he was at a loss to explain the rationale, except perhaps that the serum introduced antibodies locally. No anaphylaxis was noticed. In the same year, Laewen,<sup>5</sup> the surgical director at Marburg, discouraged by the death of several patients with fulminating furuncles of the face, injected the patient's freshly aspirated whole blood at the margins of induration of nine furuncles of the face after simple crucial incisions. The infections were progressive rather than fulminating, and the results were favorable. Several months later Laewen<sup>6</sup> described a case of fulminating furuncle of the upper lip in which, after crucial incision, 90 cc. of the patient's unmodified blood was injected just beyond the area of cellulitis. The next day the infiltration and induration were found to be merged. On the third day the temperature and swelling were down. On the sixth day the induration had spread to the other side of the face. Sixty-five cubic centimeters of the patient's blood was then injected as previously. On the ninth day the process had stopped and squeezing did not spread it. Other workers in this field were Nourney,<sup>7</sup> Linhart<sup>8</sup> and Kulm.<sup>9</sup> Schlesinger,<sup>10</sup> disagreeing with Laewen, preferred excision. He believed that the indeterminate depth of the carbuncle would prevent successful infiltration of blood beneath it.

It occurred to me that circuminjection of autogenous blood in local infections without any operative procedure had some interesting possi-

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TABLE 10.—Data in Case 10

Before Injection												
Age	Sex	Location	Duration	Amount of Pain	Temperature	Size of Indurated Area	Size of Opening	Tenderness	Culture	Amount of Blood Injected		
13	♂	back of neck	6 days	Moderate; lost sleep 5 nights	93.5	5 by 4.5 cm.	Ph-head; 2 openings	Slight	Not done	15 cc. at 7, 12 and 3 o'clock		

## After Injection

Day	Pain less; slept 7 hours	Temperature	Chill	Stiffness	Discharge	Induration	Injected Area			Time for Complete Closure 18 days	Sear Minimal
							Tenderness	Induration	Ecchymosis		
1		99	0	Slight	Few drops	5 by 3 cm.	Slight	Present	0	0	
2	0	99	0	Slight	1 cc. pus	3 by 3 cm.	Slight	Present	0	0	
3	0	99.2	0	Very slight	1 cc. pus	3 by 3 cm.	0	Present	0	0	
4	0	99.6	0	0	Profuse	3 by 3 cm.	0	Present	0	0	
8	Follow-up letter stated patient was well.										
18	0	0	0	0	No discharge	0	0	0	0	0	

TABLE 11.—Data in Case 11

Before Injection											Amount of Blood Injected 40 cc. at 1, 2, 6, 8 and 9 o'clock
Age	Sex	Location	Duration	Amount of Pain	Tempera- ture	Indurated Area	Size of Opening	Tenderness	Culture	Amount of Blood Injected	
31	♂	Back of neck	6 days	Severe; sleep- less night	99	4 by 4 cm.	Several pin- head openings	Moderate	Not done	40 cc. at 1, 2, 6, 8 and 9 o'clock	

## After Injection

Day	Pain	Temperature	Chill	Stiffness	Discharge	Induration	Injected Area			Time for Complete Closure 21 days	Sear Minimal
							Tenderness	Induration	Ecchymosis		
1	Much better; slept well	100.2	0		Very slight; purulent	Present	Present	0	0		
2	Very slight but much less than before Injection; slept well; ate whole chicken	99	0	None; turned neck easily	1 cc. pus	Present	Present	0	0	Follow-up, 13 months; sear, 2 by 1 cm.; superficial; not adherent; no induration; no pain or tenderness	
3	None except along glands; appetite fine	99	0	0	2 cc. thick pus	Less	Slight	0	0		
4	a: felt fine; slept all night	99	0	0	Profuse; 5 cc.	Slight	Very slight	0	0		
5	0	98.6	0	0	Very profuse; large slough removed from center of opening 4 by 4 cm.	0	Very slight	0	0		
6	0	98.0	0	0	Profuse; no slough; granulations at base red	0	Slight	0	0		
7	0	98.0	0	0	Very slight	0	0	0	0		
8	0	0	0	0	Very slight	0	0	0	0		Present
9	0	0	0	0	0	0	Very slight	0	0		Present
10	0	0	0	0	Very slight; granulating area smooth; 1 cc. in diameter	0	0	0	0		Present

Practically healed

to six, varies according to the extent of spread. The amount of blood injected varies with the size of the carbuncle and the amount of induration.

A fairly typical course of a carbuncle of the back of the neck treated in this manner is as follows: Immediately on the patient's recovery from the anesthesia the pain is much diminished and in some cases it has vanished. The patient may be able to turn his head laterally without pain even in cases in which this was not possible before the treatment. The anxious and painful expressions often disappear, also the frequent shooting pains referred to surrounding areas. As a rule, the first good night's sleep is obtained, but it is disturbed if pressure is put on the carbuncle. The patient feels stronger, his appetite is distinctly better, there is an improvement in his mental and physical condition, and he does not feel so feverish. The day after the treatment, pus begins to ooze out of the small openings in the center of the carbuncle and occasionally small sloughs separate. Improvement is rapid, drainage becomes profuse and the indurated and blood injected areas have merged. There is some tenderness at the sites of the injections which gradually disappears; the induration of the injected area may take two weeks to subside. The small openings in the center of the carbuncle coalesce about the third day and bright red granulations begin to appear at the base of the wound. There may be some ecchymosis at the injected area, and the skin within the injected area assumes a violaceous color. Epithelization then gradually takes place, leaving a minimal scar, which in a two year follow-up is found to be superficial, nonadherent, with no induration and in some cases almost invisible.

The cases are described according to a definite scheme, which is self explanatory, in the accompanying tables.

An analysis of the twelve cases given in the tables follows:



Fig. 3.—Same patient shown in figure 1 ten days after circuminjection, showing extent of lesion, slough and pus.



Fig. 4.—Same patient shown in figures 1, 2 and 3 on discharge forty-one days after treatment; the epithelization and absence of marked scarring should be noted.





utilization of other accessory measures, such as incision, local heat or narcotics. The following results were noted:

The infection did not spread, except in one case.

There was quick relief from pain and constitutional symptoms.

No reaction was observed after injection.

Most of the slough liquefied.

The injected blood seemed to remain in the tissues, with gradual modification, for from several days to two weeks; as evidenced by induration in the injected area, ecchymosis or both.

A violaceous color around the carbuncle appeared in an average time of six days. This might have been an outcome of passive congestion.

I believe that the time for cure was probably shorter than it would have been by surgical procedure, although it would have been impossible to have had a series of exactly the same carbuncles with surgical therapy as a control.

All the patients showed a minimal scar at the time of discharge from the hospital.

In seven of the cases, with an average follow-up of twenty-three months, the scar was superficial, minimal, nonadherent, almost invisible in some instances, and with the negligible induration in two cases.

There was no recurrence of infection locally.

For those who may be interested in the mechanism of the curative phenomena observed in these cases, it might be stated that the increased cellular activity produced by the circuminjection of autogenous blood probably prevents spread of infection and increases autolysis. To elaborate, the following suggestions are offered:

1. *Increase of Local Resistance.*—The injected blood itself produces a powerful positive chemotaxis, so that large numbers of the various leukocytes are mobilized immediately around the infected area. Gay<sup>13</sup> believes that body cells rather than body fluids are the chief factors in the defense processes against micro-organisms. He states that besides polymorphonuclear leukocytes (microphages) the large mononuclear cells of the body (wandering endothelial cells, clasmotocytes of Ranvier, macrophages of Metchnikoff, histiocytes) play a most important part in increasing local resistance. Clasmotocytes, according to Gay, show the following significant properties:

(a) When occurring in connective tissue they have pseudopodial processes known as "trailers." In exudates in serous cavities they are usually ovoid in appearance, with a large eccentric and often indented nucleus.

(b) Phagocytic power for animal cells, red blood cells, pigment, polymorphonuclear cells and bacteria.

(c) Migratory tendencies which are not as marked as in the polymorphonuclear leukocytes but more marked than in the fixed tissue endothelium.

(d) Superiority in resisting extraneous influences, which would make them valuable agents in protecting the body against bacteria.

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13. Gay, F. P.: Local or Tissue Immunity, *Arch. Path. & Lab. Med.* 1:500 (April) 1926.



Gay<sup>14</sup> and Morrison are firm in their belief that clasmatoocytes have a distinct function in the disposal of bacteria, and that they are probably more important than the polymorphonuclear leukocytes in this respect. Gay<sup>15</sup> found that broth, when injected into the simple tissue of the rabbit pleura, produces an increased resistance or active immunity to streptococcus. Granulation tissue forms so that the pleura increases in thickness about forty times. The subserosa is increased in thickness by the infiltration of enormous numbers of mononuclear cells, which, following injections of trypan blue into the cavity, can be shown to be, in significant proportion, true clasmatoocytes. Bacteria injected into the pleural cavity are found in an hour or two in the clasmatoocytes of the subserous layer under an apparently intact, though modified, serosa which in itself is never phagocytic. In preliminary experiments in pleural immunity, Gay<sup>15</sup> indicates that in advanced grades not only is the original pleura protected but also the other pleura. In this instance, histologically the pleura opposite the immunized one is normal before infection, but on injection of the test dose, protection is acquired by mobilization of previously formed clasmatoocytes in the new area. Gay<sup>15</sup> states that he believes that other substances, such as broth, would produce the same action as autogenous blood on a carbuncle. These substances have a tendency to diminish local tissue resistance in the first twenty-four hours, but blood may bridge this gap. Rivers and Tillett<sup>16</sup> corroborate some of Gay's work.

2. *Increased Action of Proteolytic Ferments.*—The greater mobilization of polymorphonuclear leukocytes and clasmatoocytes makes this possible. It was clearly noted that the slough in the carbuncles had a tendency to liquefy. Mueller<sup>17</sup> was the first to show that proteolytic enzymes occur in the cells of purulent exudates. Opie<sup>18</sup> demonstrated two proteolytic ferments in leukocytes, which act both in an acid and an alkaline medium but are more efficient in the latter. Bacteria also contain proteolytic ferments.

3. *Introduction of an Antitoxin.*—Following the recent report of Dick and Dick<sup>19</sup> that scarlet fever strains of *Streptococcus hemolyticus* produce a dermatotoxic poison for man, Mrs. Parker<sup>20</sup> demonstrated a similar poison in rabbits by injecting sterile filtrates of broth cultures of certain strains of *Staphylococcus aureus*. She also found that small amounts of the serums of many of the rabbits previously injected with filtrates for skin injuring substances easily neutralize

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14. Gay, F. P.: Local Resistance and Local Immunity to Bacteria, *Physiol. Rev.* 4:191 (April) 1924.

15. Gay, F. P.: Personal communication to the author.

16. Rivers, T. M., and Tillett, W. S.: Local Passive Immunity in the Skin of Rabbits to Infection with (1) a Filtrable Virus, and (2) Hemolytic *Streptococci*, *J. Exper. Med.* 41:185 (Feb. 1) 1925.

17. Mueller, Friederich, quoted by Kossel: *Ztschr. f. klin. med.* 13:149, 1888.

18. Opie, E. R.: Enzymes and Antienzymes of Inflammatory Exudates, *J. Exper. Med.* 7:316, 1905; The Enzymes in Phagocytic Cells of Inflammatory Exudates, *ibid.* 8:410, 1906; Experimental Pleurisy; the Part Taken by the Enzymes of Leukocytes in the Resolution of a Fibrinous Exudate, *Tr. A. Am. Phys.* 22:179, 1907.

19. Dick, G. F., and Dick, G. H.: A Skin Test for Susceptibility to Scarlet Fever, *J. A. M. A.* 82:265 (Jan. 26) 1924.

20. Parker, Julia T.: The Production of an Exotoxin by Certain Strains of *Staphylococcus aureus*, *J. Exper. Med.* 40:761 (Dec. 1) 1924.

TABLE 7.—Data in Case 7

TABLE 7.—Data in Case 7									
Age	Sex	Location	Before Injection				Tenderness	Culture	Amount of Blood Injected 60 cc. at 6 points of Injection
			Back of neck	Duration before cruciate incision; process spreading	Amount of Pain Moderate; 3 sleepless nights	Temperature 100			
Day	Pain	Temperature	Chill	Stiffness	Discharge	Induration	Tenderness	Indurated Area	Time for Complete Closure
1	0; slept well; twisted head easily	99.8	0	Slight	2 cc. thick pus; slough liquefying	Moderate	Slight	Induration 6 by 5 cm.	41 days
2	0; twisted head; felt well	100.4	0	Slight	Discharge increasing	Moderate	Slight	Slight 6 by 5 cm.	Minimal
3	0	99.4	0	Slight	Slough separating; discharge increasing	Less	Slight	Same	Follow-up, 24 months; sear, 6 by 1.5 cm.; extremely superficial, aneur. not adherent to underlying structures; whiter than surrounding skin
4	0	99	0	Slight	2 cc. pus; necrotic area larger	Less	Area of lymphangitis spreading toward mastoid	0	
5	0	99	0	Slight	More profuse; slough separating	Less	0	0	
6	Slight in area of lymphangitis	99.4	0	Slight	Less; slough not separated	Less	0	0	
7	0	99.4	0	0	Slough sticking	Less	0	0	
8	0	98.8	0	0	Area of necrosis greater; moderate discharge	Less	0	0	
9	0	99	0	0	Slough separating	0	0	Less Lymphangitis same	Present
10	0	99	0	0	Slough separating	0	0	Flaxseed poultices for lymphangitis	Present
11	0	98.8	0	0	Slough separating	0	0	Flaxseed poultices for lymphangitis	Present
12	0	98.8	0	0	Slough separating	0	0	Slight	Present
13	0	98.8	0	0	Slough separating	0	0	0	Present
14	0	98.8	0	0	Slough separating	0	0	0	Present
15	0	98.8	0	0	Slough separating	0	0	0	Present
16	0	98.8	0	0	Slough separating	0	0	0	Present
17	0	98.8	0	0	Slough separating	0	0	0	Present
18	0	98.8	0	0	Slough separating	0	0	0	Present
19	0	98.8	0	0	Slough separating	0	0	0	Present
20	0	98.8	0	0	Slough separating	0	0	0	Present
21	0	98.8	0	0	Slough separating	0	0	0	Present
22	0	98.8	0	0	Slough separating	0	0	0	Present
23	0	98.8	0	0	Slough separating	0	0	0	Present
24	0	98.8	0	0	Slough separating	0	0	0	Present
25	0	98.8	0	0	Slough separating	0	0	0	Present
26	0	98.8	0	0	Slough separating	0	0	0	Present
27	0	98.8	0	0	Slough separating	0	0	0	Present
28	0	98.8	0	0	Slough separating	0	0	0	Present
29	0	98.8	0	0	Slough separating	0	0	0	Present
30	0	98.8	0	0	Slough separating	0	0	0	Present
31	0	98.8	0	0	Slough separating	0	0	0	Present
32	0	98.8	0	0	Slough separating	0	0	0	Present
33	0	98.8	0	0	Slough separating	0	0	0	Present
34	0	98.8	0	0	Slough separating	0	0	0	Present
35	0	98.8	0	0	Slough separating	0	0	0	Present
36	0	98.8	0	0	Slough separating	0	0	0	Present
37	0	98.8	0	0	Slough separating	0	0	0	Present
38	0	98.8	0	0	Slough separating	0	0	0	Present
39	0	98.8	0	0	Slough separating	0	0	0	Present
40	0	98.8	0	0	Slough separating	0	0	0	Present
41	0	98.8	0	0	Slough separating	0	0	0	Present
42	0	98.8	0	0	Slough separating	0	0	0	Present
43	0	98.8	0	0	Slough separating	0	0	0	Present
44	0	98.8	0	0	Slough separating	0	0	0	Present
45	0	98.8	0	0	Slough separating	0	0	0	Present
46	0	98.8	0	0	Slough separating	0	0	0	Present
47	0	98.8	0	0	Slough separating	0	0	0	Present
48	0	98.8	0	0	Slough separating	0	0	0	Present
49	0	98.8	0	0	Slough separating	0	0	0	Present
50	0	98.8	0	0	Slough separating	0	0	0	Present
51	0	98.8	0	0	Slough separating	0	0	0	Present
52	0	98.8	0	0	Slough separating	0	0	0	Present
53	0	98.8	0	0	Slough separating	0	0	0	Present
54	0	98.8	0	0	Slough separating	0	0	0	Present
55	0	98.8	0	0	Slough separating	0	0	0	Present
56	0	98.8	0	0	Slough separating	0	0	0	Present
57	0	98.8	0	0	Slough separating	0	0	0	Present
58	0	98.8	0	0	Slough separating	0	0	0	Present
59	0	98.8	0	0	Slough separating	0	0	0	Present
60	0	98.8	0	0	Slough separating	0	0	0	Present
61	0	98.8	0	0	Slough separating	0	0	0	Present
62	0	98.8	0	0	Slough separating	0	0	0	Present
63	0	98.8	0	0	Slough separating	0	0	0	Present
64	0	98.8	0	0	Slough separating	0	0	0	Present
65	0	98.8	0	0	Slough separating	0	0	0	Present
66	0	98.8	0	0	Slough separating	0	0	0	Present
67	0	98.8	0	0	Slough separating	0	0	0	Present
68	0	98.8	0	0	Slough separating	0	0	0	Present
69	0	98.8	0	0	Slough separating	0	0	0	Present
70	0	98.8	0	0	Slough separating	0	0	0	Present
71	0	98.8	0	0	Slough separating	0	0	0	Present
72	0	98.8	0	0	Slough separating	0	0	0	Present
73	0	98.8	0	0	Slough separating	0	0	0	Present
74	0	98.8	0	0	Slough separating	0	0	0	Present
75	0	98.8	0	0	Slough separating	0	0	0	Present
76	0	98.8	0	0	Slough separating	0	0	0	Present
77	0	98.8	0	0	Slough separating	0	0	0	Present
78	0	98.8	0	0	Slough separating	0	0	0	Present
79	0	98.8	0	0	Slough separating	0	0	0	Present
80	0	98.8	0	0	Slough separating	0	0	0	Present
81	0	98.8	0	0	Slough separating	0	0	0	Present
82	0	98.8	0	0	Slough separating	0	0	0	Present
83	0	98.8	0	0	Slough separating	0	0	0	Present
84	0	98.8	0	0	Slough separating	0	0	0	Present
85	0	98.8	0	0	Slough separating	0	0	0	Present
86	0	98.8	0	0	Slough separating	0	0	0	Present
87	0	98.8	0	0	Slough separating	0	0	0	Present
88	0	98.8	0	0	Slough separating	0	0	0	Present
89	0	98.8	0	0	Slough separating	0	0	0	Present
90	0	98.8	0	0	Slough separating	0	0	0	Present
91	0	98.8	0	0	Slough separating	0	0	0	Present
92	0	98.8	0	0	Slough separating	0	0	0	Present
93	0	98.8	0	0	Slough separating	0	0	0	Present
94	0	98.8	0	0	Slough separating	0	0	0	Present
95	0	98.8	0	0	Slough separating	0	0	0	Present
96	0	98.8	0	0	Slough separating	0	0	0	Present
97	0	98.8	0	0	Slough separating	0	0	0	Present
98	0	98.8	0	0	Slough separating	0	0	0	Present
99	0	98.8	0	0	Slough separating	0	0	0	Present
100	0	98.8	0	0	Slough separating	0	0	0	Present
101	0	98.8	0	0	Slough separating	0	0	0	Present
102	0	98.8	0	0	Slough separating	0	0	0	Present
103	0	98.8	0	0	Slough separating	0	0	0	Present
104	0	98.8	0	0	Slough separating	0	0	0	Present
105	0	98.8	0	0	Slough separating	0	0	0	Present
106	0	98.8	0	0	Slough separating	0	0	0	Present
107	0	98.8	0	0	Slough separating	0	0	0	Present
108	0	98.8	0	0	Slough separating	0	0	0	Present
109	0	98.8	0	0	Slough separating	0	0	0	Present
110	0	98.8	0	0	Slough separating	0	0	0	Present
111	0	98.8	0	0	Slough separating	0	0	0	Present
112	0	98.8	0	0	Slough separating	0	0	0	Present
113	0	98.8	0	0	Slough separating	0	0	0	Present
114	0	98.8	0	0	Slough separating	0	0	0	Present
115	0	98.8	0	0	Slough separating	0	0	0	Present
116	0	98.8	0	0	Slough separating	0	0	0	Present
117	0	98.8	0	0	Slough separating	0	0	0	Present
118	0	98.8	0	0	Slough separating	0	0	0	Present
119	0	98.8	0	0	Slough separating	0	0	0	Present
120	0	98.8	0	0	Slough separating	0	0	0	Present
121	0	98.8	0	0	Slough separating	0	0	0	Present
122	0	98.8	0	0	Slough separating	0	0	0	Present
123	0	98.8	0	0	Slough separating	0	0	0	Present
124	0	98.8	0	0	Slough separating	0	0	0	Present
125	0	98.8	0	0	Slough separating	0	0	0	Present
126	0	98.8	0	0	Slough separating	0	0	0	Present
127	0	98.8	0	0	Slough separating	0	0	0	Present
128	0	98.8	0	0	Slough separating	0	0	0	Present
129	0	98.8	0	0	Slough separating	0	0	0	Present
130	0	98.8	0	0	Slough separating	0	0	0	Present
131	0	98.8	0	0	Slough separating	0	0	0	Present
132	0	98.8	0	0	Slough separating	0	0	0	Present
133	0	98.8	0	0	Slough separating	0	0	0	Present
134	0	98.8	0	0	Slough separating	0	0	0	Present
135	0	98.8	0	0	Slough separating	0	0	0	Present
136	0	98.8	0	0	Slough separating	0	0	0	Present
137	0	98.8	0	0	Slough separating	0	0	0	Present
138	0	98.8	0	0	Slough separating	0	0	0	Present
139	0	98.8	0	0	Slough separating	0	0	0	Present
140	0	98.8	0	0	Slough separating	0	0		

the most powerful staphylococcus poison. Normal rabbit serum, used as a control, had no detoxicating effect, except when incubated with the poison in comparatively large amounts.

In the light of these experiments, one might assume that the circulating antitoxin in the human being, when injected around the soluble toxin producing lesion, might have a beneficial effect on it.

4. *Autohemotherapy*.—Among other observers, Mathieu<sup>21</sup> and Vorschuetz and Tenckhoff<sup>22</sup> have noted a beneficial effect on local infection by the injection of the patient's own blood at a distance from the pus focus.

Laewen<sup>5</sup> believes that the lymphatics around the infected area become blocked by red cells of the injected blood. We have attempted to prove this experimentally in guinea-pigs but have been unsuccessful. Hilgenberg and Thomann<sup>23</sup> found that if poisonous doses of strychnine, curare or cocaine are injected into the tails of mice, more than deadly amounts of the poison can be tolerated if a blood infiltration is performed central to the depot (at the root of the tail). They used fluids of great viscosity, such as blood, serum and gum acacia solution, and found them much better than physiologic sodium chloride solution. Their effect resembled to some extent that of the Esmarch bandage. Laewen also believes that antibodies are introduced locally by the injection of autogenous blood. If present, I believe that their quantity is insignificant.

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21. Mathieu, C.: De l'emploi de la Methode de Descarpentries (sang hemolyse) en Chirurgie, *Rev. méd. de l'est* 51:582, 1923.

22. Vorschuetz, J., and Tenckhoff, B.: Von der Behandlung mit Eigenblut, *Deutsche Ztschr. f. Chir.* 183:364, 1923.

23. Hilgenberg, F., and Thomann, O.: Experimentelle Untersuchungen über die Aufhebung von Giftresorption durch abriegelnde Bluteinspritzung, *Deutsche Ztschr. f. Chir.* 180:267, 1923.

TABLE 9.—Data in Case 9

Before Injection										
Age 53	Sex ♂	Location back of neck	Duration 14 days	Amount of Pain Moderate; 2 sleepless nights	Temp- ture 99.0	Size of Indurated Area 5.5 by 6 cm.	Size of Opening 2 by 2 cm.	Tenderness Moderate	Culture Not done	Amount of Blood Injected 50 cc. at 8, 12, 1 and 2 o'clock
After Injection										
Day	Pain	Temp- ature	Chill	Swiftness	Discharge	Induration	Tenderness	Injected Area		Time for Complete Closure 32 days
1	Slight; slept 5 hours	99.0	0	Slight	Profuse thick slough sepi- rating	Moderate	Slight	Induration Slight	Echymosis 0	Color 0
2	Slight; slept 6 hours; turned neck easily	99.0	0	0	Profuse; slough separating; areol necrosis 3.5 cm. in diameter	Moderate	Slight	Slight; not spreading	0	Present
3	No pain; slept all night	99.1	0	0	Profuse	Less	0	Slight	0	Present
4		99.2	0	0	Profuse; slough still sticking	Less	0	Slight	0	Present
5	0	98.2	0	0	Profuse; 5 cc.; 2 pieces slough; areol necrosis 2 cm. in diameter	0	0	0	0	Present
6	0	98.3	0	0	30 cc. pus and slough	0	0	0	0	5.5 by 5.5 cm.
7	0	99.0	0	0	Profuse; no slough	0	0	0	0	Present
8	0	99.0	0	0	5 cc.	0	0	0	0	Present
9	0	98.0	0	0	2 cc.; small slough; areol necrosis 1.5 cm. in diameter	0	0	0	0	Present
11	0	98.0	0	0	1 cm. in diameter; small amount pus	0	0	0	0	Present
13	0	0	0	0	0.5 cc.; granulat- ing areol 0.5 cm. in diameter	0	0	0	0	Present
18	0	0	0	0	0	0	0	0	0	Present
21	0	0	0	0	Scab	0	0	0	0	0 by 5 cm.
25	0	0	0	0	Healed	0	0	0	0	0 by 5 cm.
32	0	0	0	0	.....	0	0	0	0	Present

and Hippocrates<sup>2</sup> and later Ambroise Paré<sup>3</sup> included under the name "commotio cerebri," or concussion, all injuries of the head, even severe cerebral laceration and intracranial hemorrhages. With increasing knowledge, there has been a tendency to limit the term concussion to those cases of injury of the head which do not show the clinical syndrome of cerebral pressure; and to those in which contusion and laceration are not apparent. A fine differentiation between concussion and microscopic contusion is not possible at present because there is no general agreement in the literature as to the exact definition of concussion. It may even be said that the literature is contradictory and confusing. Clinical and experimental investigations have proceeded without beginning on a basis of an exact definition of the meaning of the term concussion or of its scope, and so the literature continues to show many divergent views. It is, therefore, primarily necessary to obtain general agreement as to the exact definition of concussion. A pathologic definition hitherto widely taught is that concussion is part of a condition which has for its pathologic basis scattered microscopic contusions and petechial hemorrhages. On the other hand, the word concussion was originally a purely clinical term. With advancing knowledge, especially knowledge of pathology, and owing to the fact that most cranial injuries ending in death showed certain pathologic changes in the brain, the pathologic definition of concussion just indicated naturally became more acceptable. This, however, was at the expense of physiologic argument, and, as I think, unjustly so; for the essential symptoms of concussion undeniably depend on physiologic disturbances, and it has never been proved that these disturbances are caused by anatomic lesions, such as scattered microscopic contusions. Therefore, a clinical physiologic definition should be accepted. The term concussion should be used to indicate a group of symptoms which are the result of a temporary inhibition of cortical function, with or without stimulation or inhibition of one or more of the medullary centers, but which are not accompanied by pathologic lesions.

The conclusion is widely accepted among surgeons that the essentials of concussion are an immediate loss of consciousness, with or without symptoms suggesting medullary effects, and with a progressive tendency toward recovery; further, that pure concussion, that is, concussion without gross lesion, can cause immediate death. If this clinical definition is accepted, the physiologic phenomena and the symptoms may be correlated by means of animal experimentation. The information obtained from hospital cases is naturally somewhat restricted. In the

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2. Adams, F.: *The Genuine Works of Hippocrates*, New York, William Wood & Company 1:254.

3. Paré, A.: *Oeuvres complètes d'Ambroise Paré*, éd. Malgaigne. Paris, J.-B. Baillière 2:23, 1840.

TABLE 12.—Data in Case 12

Before Injection									
Age	Sex	Location	Duration	Amount of Pain	Temperature	Size of Indurated Area	Size of Opening	Tenderness	Culture
45	♂	Back of neck	9 days	Severe; sleepless 3 nights	101	8 by 6 cm.	3 by 3 cm.	Severe	Staphylococcus aureus
After Injection									
Day	Pain	Temperature	Chill	Stiffness	Discharge	Induration	Tenderness	Injected Area	
								Induration	Ecchymosis
1	Better; slept better; shooting pains to scalp and ears stopped	100.4	0	Less	Moderate; seropurulent; openings in center larger	Less	Very slight	Present	0
2	Slept all night; painless; appetite still poor	100	0	Less	2 cc. thick yellowish pus	Less	Slight	Present	0
3	Greater; did not sleep well; pain radiating forward	100.8	0	Increased	Moderate	Increased	Marked	Present	0

At this stage, because the process seemed to be spreading, the patient was sent to the hospital. He was treated with flaxseed poultices and the roentgen ray, and was discharged in two weeks without operation. Hospitalization with local heat alone probably would have cured this patient without additional therapy.



and will be taken as a typical example of severe concussion. The following account is taken from Dr. Archibald's monograph on surgical affections of the head.

Gussenbauer and a friend, while on a tour through the Alps, suffered a fall down the Eiger. The friend was rendered unconscious. Gussenbauer fortunately came to no harm. On rising, he found his friend completely unconscious; the pupils were wide; the corneal and other reflexes were abolished; all the muscles were flaccid; the face was deathly pale; and a chance wound was not bleeding. He was not breathing and looked quite lifeless. Evidently, there was both cardiac and respiratory standstill. After a short while, there returned, spontaneously, signs of life; first the pulse, very weak and slow; then the respiration, shallow and slow; then bleeding from the wound. Later, the reflexes appeared; the man gradually began to hear; half opened his eyes; and returned to a condition of semi-consciousness. After a while he fell into a sleep that lasted twenty-four hours; and it was only then that he acquired full consciousness. A week later, all concussion symptoms had disappeared, save that he had lost all memory of the events immediately preceding the accident.

While this example shows the severe type of concussion, most cases are comparatively mild, and there is almost immediate and complete recovery. Probably the best examples of such mild cases are to be found in the boxing ring; these concussions are caused by what is generally known as "the knock out blow." As a result of a sudden blow, usually on the chin, there occurs a sudden loss of consciousness, with flaccid paralysis. The fighter has ten seconds in which to recover sufficiently to get on to his feet and renew the fight, when he may go on to victory. It is inconceivable that such cases are accompanied by any gross lesion, just as it would appear doubtful that Gussenbauer's case was accompanied by a solution of continuity in the central nervous system sufficient to cause such generalized effects. Unless confined within narrow limits to the silent areas, which even then would not be sufficient to cause unconsciousness, gross lesion would give symptoms prolonged over a considerable period. Neurons destroyed in the brain tissue are not repaired but replaced by fibrous connective tissue. This suggests strongly that sequelae are due to gross lesions. Thus the clinical symptoms suggest the limitation of the word concussion to those cases which do not show any gross lesions. Retrograde amnesia may be an exception, but it is unknown whether this is functional or due to an organic lesion.

As all injuries of the head, whether concussion, contusion or hemorrhage, are caused by violence it is obvious that all three must often be present simultaneously, especially in severe cases. Such cases frequently lead to confusion in diagnosis and treatment. In cases of concussion, however, there is either spontaneous recovery or immediate death, so that this diagnosis can be eliminated in those cases in which the course is protracted. Cerebral pressure gives a typical syndrome, with raised

There are two objections to the method which might be offered. The first is that the injection of the blood might spread infection exactly like a local anesthetic. As a matter of fact, this usually does not happen. Second, the injected blood might become infected. This also did not occur. Apparently freshly injected autoblood behaves differently from extravasated blood which is the result of a trauma. The former produces little injury to tissue. If the blood of an animal is injected into one of its joints or into its pleural cavity, it is quickly absorbed, leaving no permanent adhesions. A traumatic hematoma contains a good deal of serum, and is surrounded by injured tissue, all of which must be either absorbed or extruded. In a traumatic hemarthrosis or hemo-

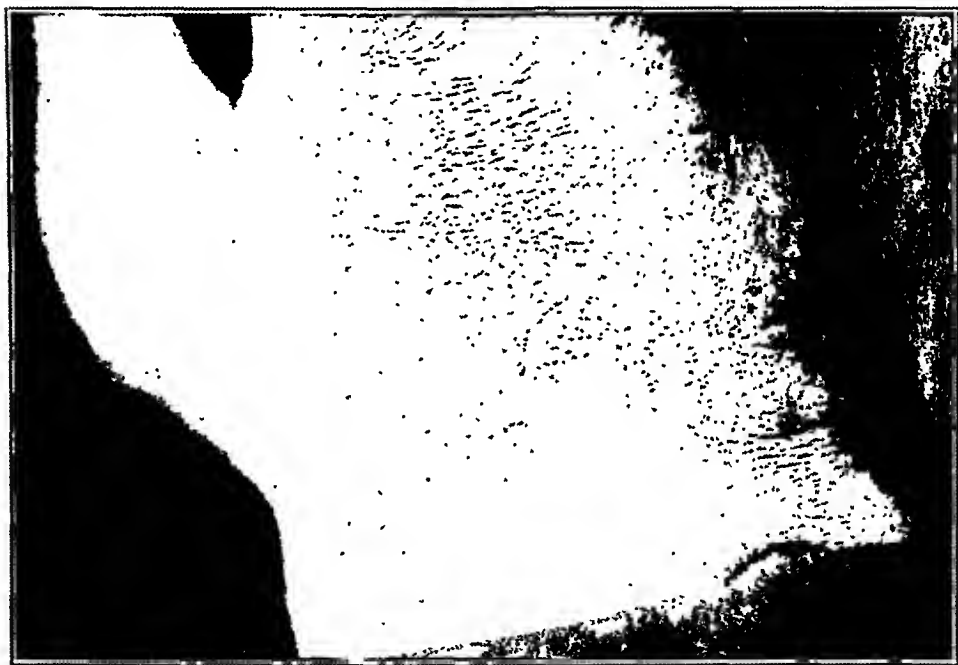


Fig. 5.—Same patient shown in figures 1, 2, 3 and 4 after twenty-four months' follow-up, showing cigaret paper-like scar, not adherent to underlying structures and not indurated.

thorax, there is slow absorption of the blood, and permanent injury to tissue results. As Laewen<sup>3</sup> expresses it, injection of blood builds a wall against the spread of bacteria while contusion paves a way for it.

#### SUMMARY

My series includes twelve cases of definite progressive carbuncles occurring in nondiabetic patients. Of these eleven were located on the back of the neck and one in the scapular region. The treatment was ambulatory and, unlike previous methods of therapy, depended solely for its efficacy on circuminjection of autogenous blood without the

lesions at autopsy in the brains of animals in which they had produced experimental concussion. Bryant,<sup>16</sup> after a careful study of the autopsy reports of Guy's Hospital over a period of twenty-five years, did not find a single fatal case of injury of the head unaccompanied by concussion, laceration or hemorrhage, and concluded that concussion and contusion were synonymous. Le Gros Clarke<sup>17</sup> reports that he had never witnessed a postmortem examination following speedy death from a blow on the head, "which did not show palpable, physical lesion of the brain." Schmaus,<sup>18</sup> Bickeles<sup>19</sup> and Friedlander<sup>20</sup> made careful histologic examinations of the central nervous tissue in man, and also in animals after experimental concussion had been produced, and constantly found minute contusions and petechial hemorrhages. Hauser<sup>21</sup> reported foci of softening in the brain of a man who died six days after an injury of the head; he suggests that had death occurred on the first day these areas would not have been found, and a diagnosis would have been made of fatal concussion unaccompanied by a gross lesion. Beudinger<sup>22</sup> demonstrated numerous degenerated ganglion cells in the brain of a man who died eighteen hours after an injury of the head. Following their experiments of producing concussion by means of repeated light blows, Koch and Filehne<sup>23</sup> performed autopsies on all their animals. They did not find any gross lesions. Scagliosi,<sup>24</sup> however, repeated these experiments and, on careful microscopic examination, found widespread minute lesions. Many other similar discoveries are reported in the bulky literature dealing with this aspect of concussion, but these will suffice to show the strong reasons for the reversal of opinion formed after the publication of Littré's work.

Nevertheless, the conclusion that concussion and contusion were synonymous did not gain universal acceptance. Von Bergmann<sup>25</sup> states that there are undoubtedly cases of death occurring as a result of pure concussion unaccompanied by any anatomic histologic changes. Cush-

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16. Bryant, T.: *Lancet* 2:405 and 507, 1888.

17. Clark, Le Gros: *Diagnosis of Visceral Lesions*, ed. 1, 1870; quoted by Miles, A.: *Brain* 15:157, 1892.

18. Schmaus, H.: *München. med. Wchnschr.* 37:485, 1890; 46:75, 1899.

19. Bickeles: *Arb., a. d. Inst. Prof. Obersteiner's*, III; quoted by Schmaus, H.: *München. med. Wchnschr.* 46:79, 1899.

20. Friedländer, C.: *Virchows Arch. f. path. Anat.* 75:24, 1879.

21. Hauser, G.: *Deutsches Arch. f. klin. Med.* 65:433, 1900.

22. Beudinger, quoted by Archibald, E.: *Am. Pract. Surg.*, ed. by J. D. Bryant and H. Buck, New York, William Wood & Company 5:150, 1908.

23. Koch, W., and W. Filehne: *Arch. f. klin. Chir.* 17:190, 1874.

24. Scagliosi, G.: *Virchows Arch. f. path. Anat.* 152:487, 1898.

25. Von Bergmann: *Deutsche Chir.* 30:341, 1880.

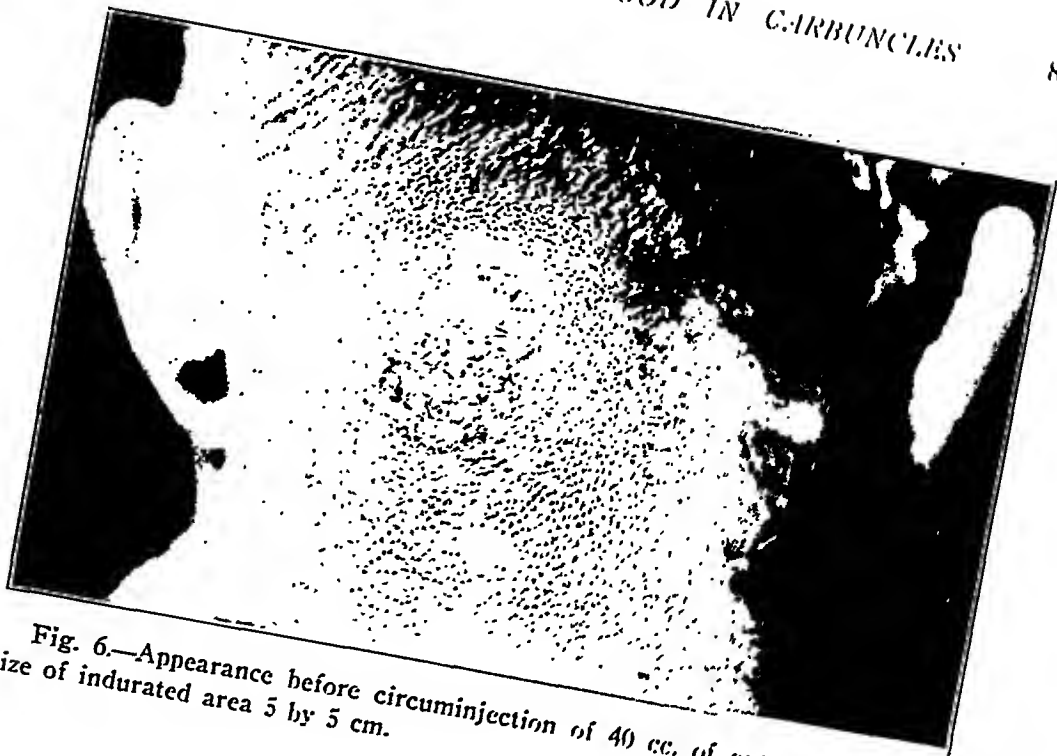


Fig. 6.—Appearance before circuminjection of 40 cc. of autogenous blood; size of indurated area 5 by 5 cm.



Fig. 7. Appearance after circuminjection of 40 cc. of autogenous blood; size of indurated area 5 by 5 cm.

due to hyperacute compression of the brain as the cause of the symptoms of concussion."

Cannon<sup>32</sup> found further support for this hypothesis in his demonstration that the initial rise of intracranial pressure, due to a blow causing inbending of the skull, was sufficient to prevent blood entering the cranial cavity. It is well known that cerebral anemia leads to paralytic symptoms similar to those of concussion. Hill<sup>35</sup> produced unconsciousness and spasm in animals by ligating the four arteries to the head, confirming the results of Kussmaul and Tenner,<sup>36</sup> who produced immediate loss of consciousness and voluntary movement by ligating the innominate artery and the left subclavian. Convulsions occurred in from 10 to 45 seconds. The unconsciousness and the flaccid paralysis seen in syncopal attacks are usually ascribed to cerebral anemia.

In a thorough experimental investigation of concussion, Polis<sup>37</sup> found that he could produce concussion more readily if he first ligated one or more of the arteries to the brain. He finally concluded that cerebral anemia alone would cause concussion, and that concussion was the result of two factors—cerebral anemia and "ébranlement" or molecular disturbance. Kocher,<sup>31</sup> Kramer,<sup>38</sup> Cannon<sup>32</sup> and others, after experimental investigation, supported the hypothesis that cerebral anemia is the sole cause of concussion.

Fischer,<sup>39</sup> and later Miles,<sup>40</sup> thought that the cerebral anemia was due to reflex contraction of the blood vessels owing to the sudden movements of the cerebrospinal fluid following the blow, which was assumed to stimulate the restiform bodies. In the light of present knowledge concerning the vasomotor supply of cerebral vessels, this theory must be abandoned.

Witkowski<sup>41</sup> produced a condition similar to concussion in the frog after removal of the heart. Cerebral anemia could hardly be a factor under these circumstances. Though the evidence supporting the theory that cerebral anemia is the direct cause of concussion appears to be comparatively conclusive, several investigators, Tilman,<sup>42</sup> Rahm,<sup>43</sup> Bres-

35. Hill, L.: *The Cerebral Circulation*, London, 1896.

36. Küssmaul and Tenner, quoted by Hill, L.: *The Cerebral Circulation*. London, 1896.

37. Polis, A.: *Rev. de chir.* 14:274 and 645, 1894.

38. Kramer, S. P.: *Ann. Surg.* 23:163, 1896.

39. Fischer, H.: *Volkman, Samml. klin. Vortr.* se. 1 27:219, 1871.

40. Miles, A.: *Brain* 15:153, 1892.

41. Witkowski, L.: *Virchows Arch. f. path. Anat.* 69:498, 1877.

42. Tilman: *Arch. f. klin. Chir.* 59:236, 1899.

43. Rahm, H.: *Zentralbl. f. Chir.* 47:146 (Jan.-June) 1920.

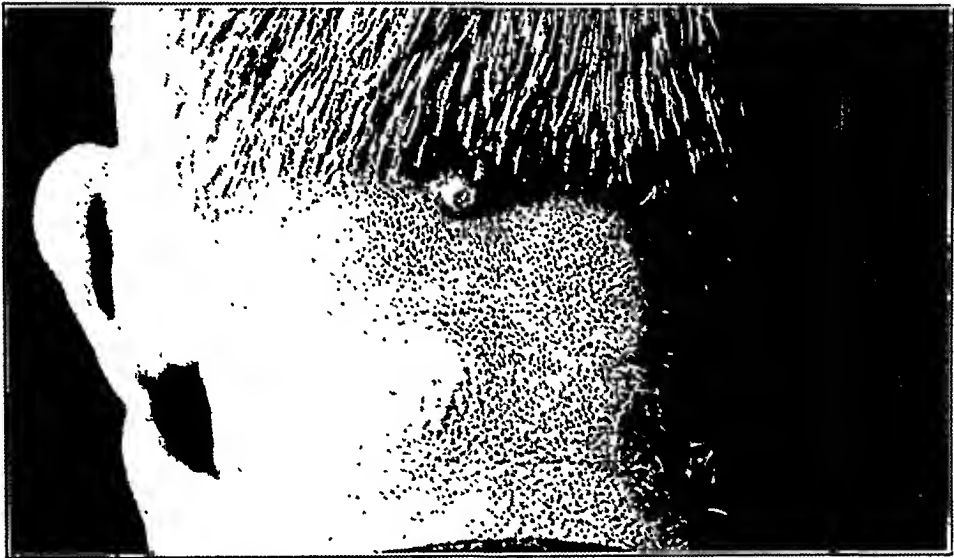


Fig. 8.—Patient shown in figures 6 and 7 on discharge thirteen days after circuminjection.



Fig. 9.—Patient shown in figures 6, 7 and 8 after twelve months follow-up, showing scar almost invisible, not adherent to underlying structures, and with no induration or depression.

thesis. That reflex cerebral anemia of any generalized extent does not occur, has already been stated.

The recent work of Breslauer<sup>44</sup> is not well known. Breslauer found that he could not produce unconsciousness by manual pressure on the cerebrum in dogs, for only when the medulla was involved did unconsciousness occur. He concludes that concussion is due to purely medullary effects. All physiologic evidence, however, tends to place the seat of consciousness in the cortex, and mild cases of concussion show scarcely any stimulation or inhibition of the medullary centers, so that it is difficult to accept Breslauer's reasoning.

A different and interesting line of thought was followed by Tilman,<sup>42</sup> who ascribed concussion to the tearing apart of the white and gray matter. As the white and gray substance of the brain have different specific gravities, they attain different degrees of acceleration in the induced field of gravity set up by an impact on the head. The tendency is for them to be torn apart, the resulting solution of continuity causing unconsciousness. The prompt recovery in most cases of concussion makes this hypothesis untenable. Rahm,<sup>43</sup> however, applies this line of reasoning to the cell particles forming nervous tissue. Protoplasm is an emulsion containing, among other things, lipoids, large protein molecules and electrolytes suspended in a watery base. These particles, having different specific gravities, take up new positions relatively in response to the new gravitational field set up by the violent movement of the brain in toto (Felizet) which invariably follows a severe impact. Until these particles resume a normal equilibrium in the earth's gravitational field, the cells cannot function. Thus the generalized paralytic conditions seen in concussion are explained. This is purely hypothetical, but is apparently in accord with physical possibilities. Examination of the active cells, vitally stained, shows the particles of the protoplasm in constant movement. This, however, does not altogether rule out the possibility of Rahm's hypothesis being correct to a certain degree.

Trendelenburg<sup>47</sup> denied that concussion is caused by anemia, suggesting that the unconsciousness is caused by a physiologic loss of function of nerve cells, which corresponds closely to that produced by narcosis. I would suggest, however, that narcosis is invariably due to a chemical agent, usually a lipid solvent, which apparently reverses the polarity of the synapse (Bayliss<sup>48</sup>) replacing excitation by inhibition. It is difficult to give sound physicochemical reasons for an analogy between narcosis and concussion. The one is a chemical effect on the synapsis first, the other purely mechanical.

47. Trendelenburg, F.: *Deutsches med. Wchnschr.* 36:1, 1910.

48. Bayliss, W. M.: *Principles of General Physiology*, London, Longmans, Green & Company, p. 427, 1920.

# CEREBRAL CONCUSSION \*

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MONTREAL

The present investigation was begun at the suggestion of Dr. Edward Archibald, in order to determine the physiologic response of the brain to an injury which might conceivably cause coincident concussion and compression. The symptoms of concussion, lasting for some hours, might be masked by and have to be distinguished from, those of an oncoming compression. This idea was suggested by clinical observation of certain patients suffering from severe cranial injury, in whom it was found that death supervened with a blood pressure, a pulse rate and a respiratory rhythm which remained approximately normal until near the end. The hypothesis which, in his conception, might explain such unusual behavior on the part of the vital centers, consisted in the assumption that the well-known opposite effects of concussion and of compression were neutralizing each other; that the raised blood pressure, slowed pulse rate and deepened respiration of compression were brought approximately to normal by the antagonistic concussion effects of low blood pressure, rapid pulse rate and hastened, shallow breathing.

In the original few experiments of this research I aimed at establishing, first of all, the effects of pure concussion in the dog and in the cat as a necessary preliminary to later experiments in which I contemplated the addition of more or less simultaneous compression lesions. This was the more necessary in that there admittedly exists, in spite of a considerable body of experimental work, a great deal of indefiniteness, not to say confusion, in the actual knowledge of concussion, particularly as to its physiology and pathology.

It may be said at the outset that these latter experiments designed to elucidate the original hypothesis have been postponed for the time being, because it soon became obvious that our ideas of concussion itself must be more definite, and there must be a much more general agreement than at present exists. Consequently, the work here recorded represents an attempt at establishing the essential pathologic and physiologic foundation of pure concussion.

Concussion is a clinical term applied to a condition following injury of the head. Originally it was broad in its scope, so broad that Galen <sup>1</sup>

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\* From the Department of Physiology and Experimental Medicine, McGill University.

\* The expenses of this research were defrayed in part by a grant from James Cooper Fund of McGill University for research in Experimental Medicine.

1. Galen, quoted by Polis, A.: *Rev. de chir.* 14:273, 1894.



2. Electrical current on the medulla oblongata.
  - (a) A weak induction current.
  - (b) Galvanic current of 120 volts.
3. Direct mechanical pressure on the medulla oblongata.
4. Cerebral anemia.

The striking similarity in the alterations in blood pressure curve and respiratory rhythm produced by these different means readily shows the impossibility of demonstrating the etiology of concussion by these methods.

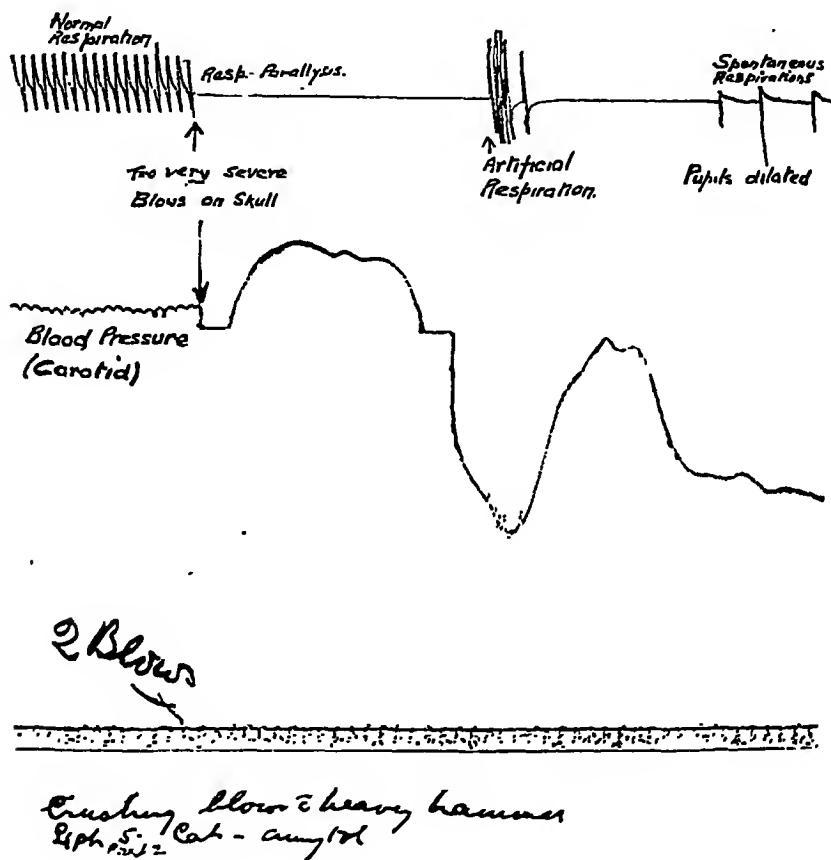


Fig. 1.—Respiratory and blood pressure changes following a severe blow on the head of a cat. Note arrest of respiration with an immediate fall in blood pressure, followed by a rise.

#### EXPERIMENT 1.—Effect of severe blows on the head.

A well nourished cat was used for this experiment. The first blow was delivered on the head with a wooden mallet weighing 175 Gm. The blow was moderately severe but did not produce any marked changes in blood pressure, although a slight rise was evident with a deep respiratory effort. Two severe blows were now inflicted on the head of the same animal with a metal mallet weighing 400 Gm. Respiration immediately stopped, with a sudden fall of blood pressure and arrest of the heart action. The blood pressure changes after the recovery of the immediate fall shown in figure 1 are essentially those following arrest of respiration in asphyxia.

patients who die of injury of the head, autopsy practically always shows numerous contusions and petechial hemorrhages in the brain. The majority of investigators have concluded that concussion and contusion are synonymous. Rare cases, however, have been reported in which postmortem examination did not show any gross lesion. Such deaths occur almost instantaneously at the moment of the accident. When death occurs later, autopsy always shows lesions caused by contusion. If the foregoing restricted definition of concussion is accepted, the latter cases must be considered as cases of concussion plus contusion. It is consequently unnecessary to endeavor to analyze the symptoms of a mixed condition of concussion and contusion in a study of concussion. The symptoms of concussion are immediate and generalized; those of contusion, progressive and tending to localization. Such a conception eliminates a great deal of the pathologic and physiologic research which has been made concerning concussion, as this research has been based on an investigation of both concussion and contusion. Nevertheless, I shall review this work, as such a review will show the need of a general agreement concerning the definition, and will also be useful later in showing that the term concussion should be limited to designate the condition which is the immediate result of an injury of the head from which the patient gradually recovers or which results in immediate death. Working on this fundamental conception, I shall offer evidence to explain the etiology of concussion, its relation to the symptoms resulting from the effects on the medullary centers, and the relation of concussion to contusion.

#### SYMPTOMS OF CONCUSSION

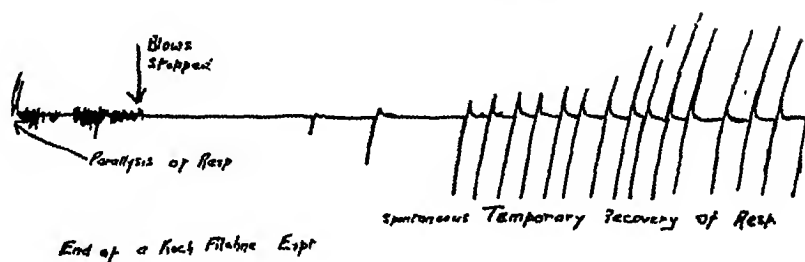
Concussion is always caused by an impact on the head, resulting in immediate unconsciousness. Light blows on the head often cause transient vertigo, grogginess, "sparks before the eyes" and similar symptoms but such a condition is of little clinical interest and appears to be largely the result of a mechanical stimulation applied to the central nervous system by means of the blow. Immediate unconsciousness is generally accepted as the constant symptom in concussion. The symptoms of concussion are mainly referable to the cortex, to the medullary centers and to a certain degree to the proprioceptor system, especially the labyrinth. It is presumably the stimulation of the labyrinth which results in the vertigo following the transient unconsciousness. The cortical symptom is the immediate, generalized paralysis of the psychic areas, while the medullary symptom depends on the severity of the blow, and is either stimulation or inhibition of the bulbar centers, which causes changes in the blood pressure, pulse rate and respiratory rhythm.

Cases of concussion are rarely seen by a trained observer from the moment of onset. Gussenbauer's<sup>4</sup> classic case has not this disadvantage

4. Gussenbauer, quoted by Archibald, E.: *Am. Pract. Surg.*, ed. by J. D. Bryant and H. Buck, New York, William Wood & Company 5:147, 1908.



Fig. 3.—Early effect of repeated light blows on the head of a dog. Note the stimulation of the respiratory and vasomotor centers.



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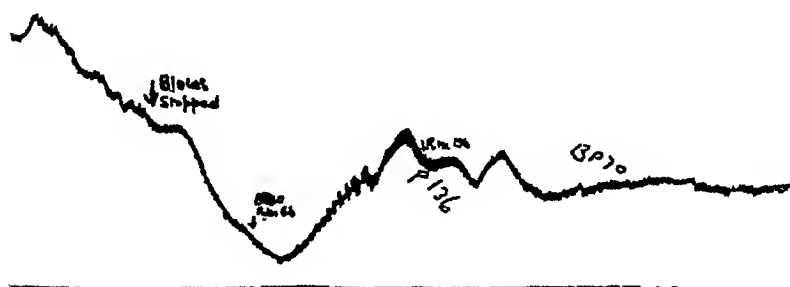


Fig. 4.—End of experiment shown in figure 2. Note that the respiratory center is temporarily paralyzed. The blood pressure rapidly falls, probably due to exhaustion of the vasomotor center.

blood pressure and slowed pulse rate. If this conception is accepted, the differential diagnosis of injury of the head becomes comparatively simple, and the factors concerned in the causation of symptoms can be analyzed.

#### RELATION OF CONCUSSION TO CONTUSION

A review of the literature dealing with the question of the relationship of concussion and contusion shows a great divergence of opinion. Further experimental evidence is required to settle the question as to whether concussion can occur without accompanying gross lesions. Experimental evidence will be given later to support this view.

Boirel,<sup>5</sup> in 1677, was the first to suggest that some cases of injury of the brain were so transient that accompanying lesions of the brain could be excluded. This opinion found marked support in the observations made at an autopsy performed by Littré<sup>6</sup> on a young man who died instantaneously on throwing himself, head first, against a prison wall. Littré did not find any microscopic contusions nor intracranial hemorrhages. Others, Sabatier,<sup>7</sup> and Boyn,<sup>8</sup> and Mourier<sup>9</sup> gave similar negative reports. The diagnosis of concussion thus became limited to those cases which did not show any gross lesions. A reversal of opinion soon occurred, when more careful microscopic observations on the part of better trained men persistently revealed the finer lesions of contusions. Ferrari,<sup>10</sup> working in Kocher's laboratory, showed that in the flinging movement of the brain in response to severe blows on the head, the soft brain struck the bony covering with sufficient force to break small glass ampules buried in the brain tissue at a depth of 5 mm. Kocher,<sup>11</sup> on this evidence, concluded that concussion and contusion were synonymous. Fano<sup>12</sup> considered the symptoms in injury of the head due to contusion, not to concussion. Alquié<sup>13</sup> wrote "la commotio comme lésion différant essentiellement de la contusion est une invention imaginaire." Pirogoff<sup>14</sup> and Beck<sup>15</sup> always found gross

5. Boirel: *Traité des plaies de tête*, 1677.

6. Littré *Acad. roy. de sc. de Paris*, 1705, p. 54; quoted by Polis, A.: *Rev. de chir.* **14**:274, 1894.

7. Sabatier: *Med. Operat.* **2**:400; quoted by Miles, A.: *Brain* **15**:154, 1892.

8. Boyn: *Thèses de Paris*, no. 4, 1818.

9. Mourier: *Thèses de Paris*, no. 119, 1834.

10. Ferrari, reported by Kocher, in Nothnagel: *Spezielle Pathologie und Therapie. Hirnerschütterung*, Vienna, Alfred Hölder, 1901, p. 320.

11. Kocher, T., in Nothnagel: *Spezielle Pathologie und Therapie, Hirnerschütterung*, Vienna, Alfred Hölder, 1901, p. 267.

12. Fano: *Mém. sur la commot. du cerveau*, *Mém. Soc. de chir.* **3**:163, 1853; quoted by Polis, A.: *Rev. de chir.* **141**:278, 1894.

13. Alquié: *Gaz. méd. de Paris*, 1865, pp. 226, 254, 314, 382, 396, 463, 500.

14. Pirogoff, quoted by von Bergmann: *Deutsche Chirurgie*, 1880, p. 296; and by Trendelenburg: *Deutsche. med. Wchnschr.* **36**:1, 1910. Pirogoff: *Grundzüge der allgemeinen Kriegschirurgie*, Leipzig, p. 77, 1864.

15. Beck, B.: *Virchows Arch. f. path. Anat.* **75**:207, 1879.

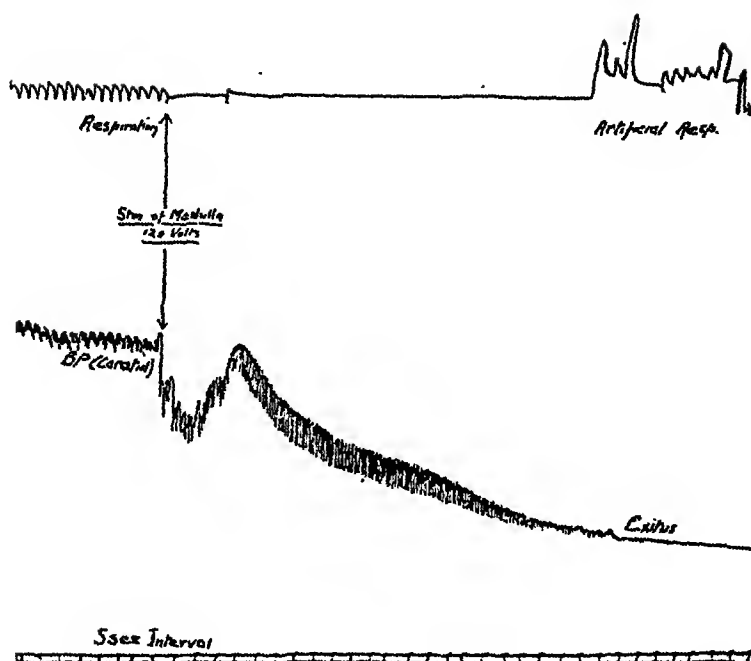


Fig. 6.—Effect of a current of 120 volts on the medulla. Note the immediate paralysis of respiration with stimulation of the vagus and vasomotor centers.

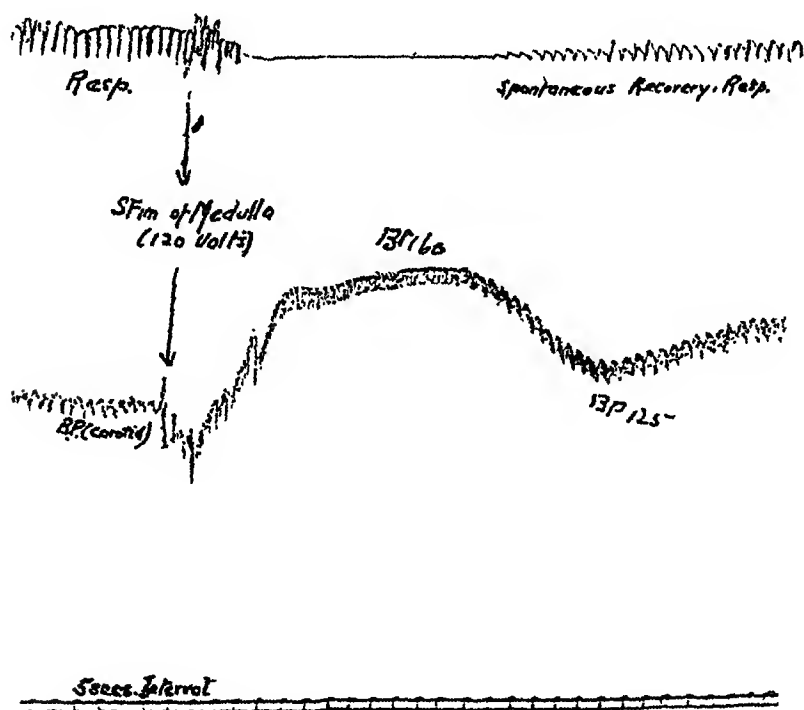


Fig. 7.—Effect of 120 volts of direct current applied to medulla with recovery of respiration.

ing,<sup>26</sup> Trotter,<sup>27</sup> Hutchison<sup>28</sup> and others make similar statements. Savory,<sup>29</sup> while denying the occurrence of death in these cases without accompanying gross lesions, says that the effects must be due to the shock of the violence rather than to the lesions. Since this question remains in doubt, I will give experimental evidence later to support the original assumption that concussion and contusion are separate and distinct clinical entities, frequently associated, but with very different symptoms and prognosis, except in borderline cases.

#### HYPOTHESIS RELATING TO THE ETIOLOGY OF CONCUSSION

Many hypotheses have been promulgated in regard to the etiology of concussion, none of which have been universally accepted. Following the work of Boirel and Littré, Petit<sup>30</sup> suggested that concussion was due to the vibrations set up in the skull by the blow and transmitted to the brain. This so-called "vibration theory" found wide acceptance, but was disproved by Alquié who demonstrated that the brain did not vibrate under these conditions but moved as a whole. This fact has been amply confirmed since that time by Cushing,<sup>31</sup> Cannon<sup>32</sup> and others.

Felizet<sup>33</sup> first demonstrated that a blow on the skull caused a diminution of the intracranial volume by dropping a blackened skull filled with paraffin on a hard floor. A large round or oval blackened area was made on the floor and the paraffin showed an area of indentation. The cranium, possessing a considerable degree of elasticity, responds to violence by bending inward. Stromeyer<sup>34</sup> was the first to suggest that this lessening of the volume of the cranial cavity forces out the fluids in the skull, thus leading to cerebral anemia which results in concussion. This hypothesis is still widely accepted. Trotter,<sup>27</sup> in 1925, discussing various hypotheses, says: "We can accept none of these hypotheses as a substitute for that which regards cerebral anaemia

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26. Cushing, H.: *Surgery of the Head*, in *Surgery*, ed. by W. W. Keen, Philadelphia, W. B. Saunders Company 3:182, 1908.

27. Trotter, W.: *A. System of Surgery*, ed. by C. B. Choyce, London, Cassell & Company 3:468, 1923.

28. Hutchinson, J.: *Illustns. Clin. Surg.*, quoted by Miles, A.: *Brain* 15:154, 1892.

29. Savory, W. S.: *St. Barth. Hosp. Rep.* 5:72, 1869.

30. Petit, J. L.: *Traité des maladies chirurgicales*, Paris 1:1774; quoted by Polis, A.: *Rev. de Chir.* 14:275, 1894.

31. Cushing, H.: *Am. J. M. Sc.* 124:375, 1902; 125:1017, 1903; *Bull. Johns Hopkins Hosp.* 12:290, 1901.

32. Cannon, W. B.: *Am. J. Physiol.* 6:91, 1901.

33. Félizet: *Recherches anat. et expér. sur les fractures des crânes*, Paris, 1873; quoted by Polis: *Rev. de chir.* 14:280, 1894.

34. Stromeyer, quoted by König, F.: *Eléments de path. chir. spéciale*, 1:66; quoted by Polis, A.: *Rev. de chir.* 14:281, 1894.

The striking similarity of these results is readily apparent if they are compared with similar tracings showing the effects of complete cerebral anemia (fig. 13) and of asphyxiation (fig. 14).

These tracings appear to show that the marked blood pressure changes produced when respiratory arrest is caused by any means are due to asphyxiation. The respiratory center is always the first to be

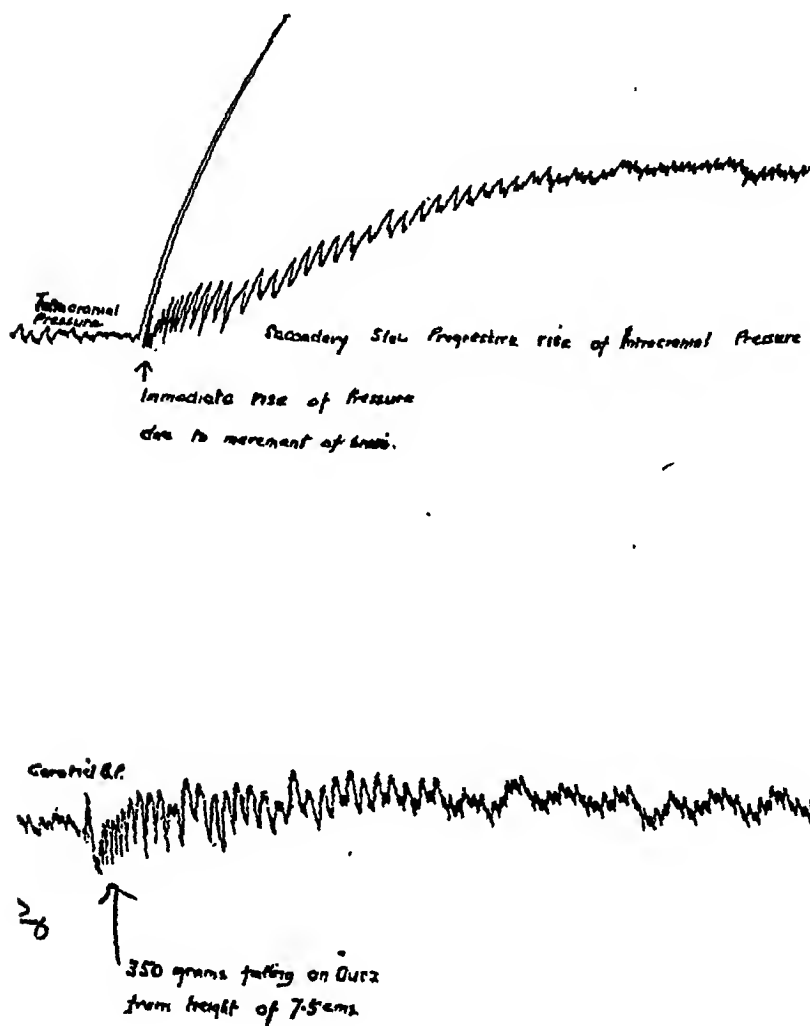


Fig. 10.—Effect on the intracranial pressure of 350 Gm. falling on the dura from a height of 3 inches. Note the immediate rise of intracranial pressure due to the movement of the brain, also the gradual rise due to the resulting edema (Cannon<sup>22</sup>).

paralyzed. With mechanical effects not severe enough to paralyze the respiratory center, a marked stimulation of respiratory movements occurs: further, there is an immediate fall of blood pressure, shown by Kocher<sup>11</sup> to be due to vagus stimulation. He pointed out that this fall did not occur when the vagus had been sectioned previously. This sudden fall soon gives way to a rise of blood pressure, due to early

lauer,<sup>44</sup> Duret,<sup>45</sup> Koch and Filehne<sup>23</sup> arrived at very different conclusions.

For instance, the opposite conclusions of Koch and Filehne<sup>23</sup> are most striking. They produced concussion by means of repeated light blows in place of the single severe blows used by most other investigators. Repeated light blows would not alter the conformation of the skull to a degree sufficient to cause cerebral anemia, but might, through summation of effect, cause an effect on the central nervous system similar to that caused by a single severe blow. These investigators concluded that concussion was the result of molecular disturbance or "ébranlement." Bergmann<sup>25</sup> supported these conclusions, and the hypothesis received considerable popularity. By molecular disturbance they evidently meant that concussion was due to a direct mechanical effect on the structural equilibrium of the cells.

Brief mention must be made of Duret's<sup>45</sup> theory of cerebrospinal shock as the cause of concussion. Duret forced fluid into the lateral ventricles to reproduce the sequence of events in the skull following the appearance of the zone of indentation caused by a blow. This lessening of the volume of the skull raises the intracranial pressure so that the cerebrospinal fluid in the ventricles is forced violently through the aqueduct of Sylvius. It then is supposed to impinge on the floor of the fourth ventricle, and to cause the minute contusions and petechial hemorrhages so often found in the region of the aqueduct in persons dying from the results of injury of the head. Duret produced similar lesions in his experiments, and considered these lesions as the pathologic basis of concussion. The paralytic symptoms of concussion were due to reflex anemia, the wave of cerebral spinal fluid stimulating the restiform bodies which caused reflex contraction of the intracranial blood vessels. Miles,<sup>40</sup> after a series of experiments of a similar nature, later supported Duret's work. He considered, further, that the scattered petechial hemorrhages so often found in persons dying of concussion were due to pressure changes on the arterioles caused by this sudden rush of cerebrospinal fluid. This produced rupture of the thin-walled vessels. As opposed to this theory, Tilanus and Deucher<sup>46</sup> were able to produce experimental concussion after aspirating the cerebrospinal fluid. Kocher<sup>11</sup> later demonstrated lesions in a patient who had not suffered a primary loss of consciousness similar to those described by Duret. These experiments, together with the difficulty of considering the results of a blow causing concussion as similar to the increase of intracranial pressure produced by Duret, have led to the abandoning of his hypo-

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44. Breslauer: Beitr. z. klin. Chir. 121:590. 1921.

45. Duret: Arch. de physiol., 1874, p. 320: quoted by Tilmann: Arch. f. klin. Chir. 59:239, 1899.

46. Deucher: Deutsche Ztschr. f. Chir. 35:145.



The conclusion drawn from these results is that a mechanical effect, such as concussion appears to be, if of a moderate degree, will stimulate the medullary centers, but if of sufficient severity will tend to paralyze them. Von Bergmann has stated that mild degrees of concussion are always accompanied by a slower pulse rate and a rise of blood pressure with a somewhat greater respiratory effort, which is evidently a mechanical stimulation of the centers concerned. Ferrari has shown that in the movement of the brain following an impact on the head there is considerable mechanical violence to the brain. Gussenbauer's case, cited above,

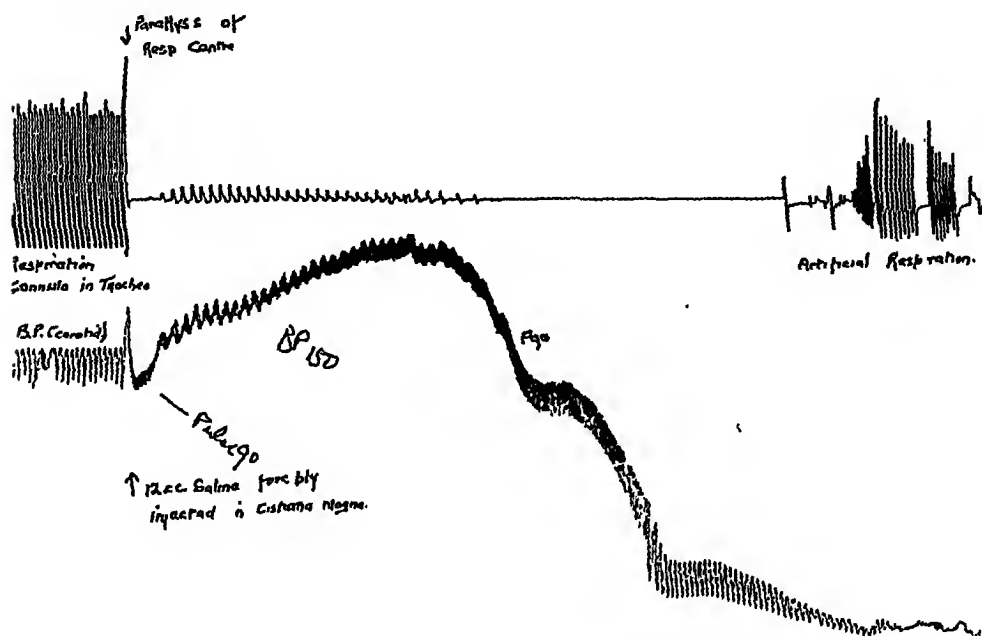


Fig. 12.—Effect of 12 cc. of physiologic sodium chloride forcibly injected into the cisterna magna. Note the similarity of the blood pressure changes to those in asphyxia.

exemplifies this mechanical effect of a sufficient severity to paralyze the respiratory center temporarily. The arrest of the heart was evidently due to vagus stimulation inhibiting the heart action. Thus mechanical violence alone could readily produce the symptoms seen in concussion. Cerebral anemia acts in precisely the same manner; moderate anemia stimulates the medullary centers, while severe anemia paralyzes the respiratory center. Study of the blood pressure and respiratory changes, therefore, will never assist in explaining the place of anemia in the causation of concussion. As there is experimental evidence that anemia

## MEDULLARY EFFECTS IN CONCUSSION

The confusion concerning the physiologic and pathologic basis of concussion is thus evident. Careful examination of the experimental methods adopted by past investigators in the study of concussion shows that in most cases a general anesthetic has been used. This obscures the predominant symptom of concussion, namely that of immediate and complete unconsciousness. Further, cats, dogs and rabbits have been used for most experiments. As these animals, belonging to a much lower order in the scale of evolution than man, depend to a much greater degree on spinal reflexes, the results of injury of the head might correspondingly be different. Again, most investigators have carefully recorded the blood pressure, the pulse rate and the respiratory rhythm, noting the changes produced by blows on the head, and have drawn conclusions from them. The vast majority of mild cases, however, show very slight if any medullary effects while the severe cases show an immediate arrest of respiration with stimulation of the vagus and vasomotor centers. In the present investigation many of the experiments of previous workers were repeated, but it soon became evident that little could be gained from such methods. To cause medullary effects, the blows are necessarily sufficiently severe to cause coincident contusion and hemorrhage. The medullary effects produced are those of stimulation or inhibition of the bulbar centers. Thus any agency which will stimulate or inhibit these centers, produces changes similar to those produced by blows on the head. The onset of concussion consequently cannot be judged from changes in the blood pressure, the pulse rate or the respiratory rhythm.

## EXPERIMENTAL INVESTIGATION OF MEDULLARY EFFECTS UNDER VARYING CONDITIONS

In the following experiments, the work of several previous investigators was repeated in order to judge the value of blood pressure changes and alterations in the respiration and pulse rate in the demonstration of the physiologic and pathologic changes in varying types of injury of the head. Dogs and cats were used and were anesthetized with either ether or amytal. The respiratory rhythm was recorded through a tube inserted in the trachea, one of the arms of which connected with a writing lever resting on a tambour. The blood pressure was recorded in the usual manner by connecting a cannula placed in the carotid to a mercury manometer, on one arm of which floated the writing pointer. Comparison was made of the medullary effects produced by the following agencies.

1. Blows on the head.
  - (a) Single severe one.
  - (b) Repeated light taps.

may have a place in the causation of concussion (Cannon, Felizet), and as it is generally recognized that cerebral anemia will produce paralytic conditions similar to those occurring in concussion, it is necessary to show conclusively whether sudden anemia will or will not produce immediate unconsciousness. The inbending area of the elastic skull following a blow which forces out the fluids from the skull will immediately spring out again. Any anemia, therefore, must be exceedingly transient, certainly less than one second in duration. It seems improbable that an anemia of such a short duration could cause such widespread paralytic symptoms. All the cells of the central nervous tissue are not adjacent to capillaries, and these cells could hardly be affected by such a transient anemia. Further, it has never been demonstrated, and seems very unlikely, that in the frequent cases of the "knock out" blows the indirect force of the blow on the base of the skull can cause a sufficient diminution in the size of the cranial cavity to squeeze out the fluid contents. It, therefore seems, *a priori*, very unlikely that cerebral anemia is the cause of concussion. The following experiments give considerable support to this contention.

#### CEREBRAL ANEMIA PROBABLY NOT CAUSE OF CONCUSSION

##### EXPERIMENT 1.—*Concussion in the heartless frog.*

The heart is removed from a frog under light general anesthesia. On recovery from the anesthesia the frog appears to be conscious. If it receives a sharp blow on the head, a condition arises which appears to be analogous to concussion. The frog lies on its back, without moving and all reflexes are lost. In a few moments it recovers and rights itself and all reflexes return. A blow on the head of the normal frog produces a similar condition analogous to that of concussion in man.

##### EXPERIMENT 2.—*Complete cerebral anemia in the rabbit without loss of consciousness.*

Under a local anesthetic (procaine hydrochloride), the sternum is opened in the midline, care being taken not to open the pleura. The ascending aorta is dissected out, and clamped for periods of from 1 to 7 seconds. It is evident that this will produce an immediate anemia of much longer duration than that produced in concussion. The animal in this case does not lose consciousness. Immediately on putting it on its feet, it struggles and gives all signs of being conscious. Trapping experience shows that when rabbits are given a sharp blow on the head they immediately lose consciousness for several seconds. Concussion can therefore readily be produced in rabbits by means of blows on the head, but not by transient cerebral anemia of five seconds' duration.

These experiments show that in both the frog and the rabbit, though a condition exactly simulating concussion can be produced readily, it is not the result of cerebral anemia. A transient cerebral anemia even of five seconds' duration does not produce unconsciousness. It is evident, then, that these experiments confirm the arguments stated above, that cerebral anemia is not the cause of concussion. In early experiments

EXPERIMENT 2.—*Effect of repeated light blows on the head of animals.*

This experiment was based on those of Koch and Filehne. Dogs were used under amytal anesthesia. The repeated light blows, inflicted with a light wooden mallet produced marked stimulation of the bulbar centers as seen in the deep, rapid respirations and rising blood pressure. There was also slowing of the pulse rate, evidently due to stimulation of the vagus center. When these blows were continued over a long period, respiratory paralysis finally occurred. With the arrest of respiration, the pulse rate and blood pressure curve (figs. 3 and 4) followed changes almost similar to those noted in the previous experiment (fig. 1) although there was not the marked initial rise in the blood pressure. This was evidently due to the fact that the vasomotor center had been stimulated by the

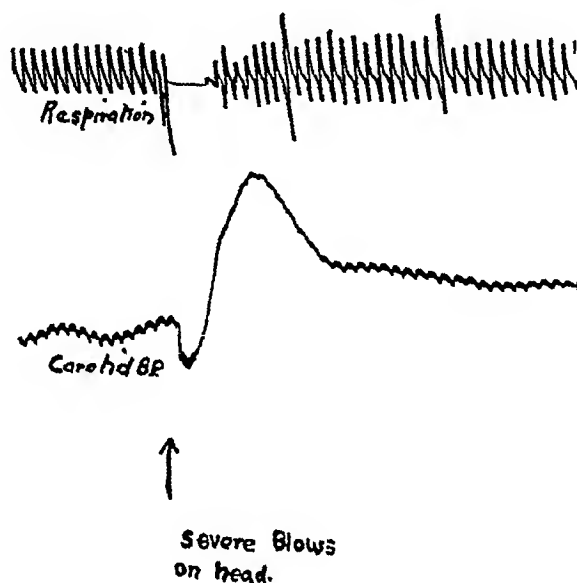


Fig. 2.—Respiratory and blood pressure changes following a severe blow on the head of a cat.

blows from the outset of the experiment, and was not capable of further stimulation by the increasing H-ion concentration resulting from this secondary asphyxiation.

EXPERIMENT 3.—*Effect of electrical stimulation of the medulla.*

A dog was used under amytal anesthesia in this experiment. The medulla was exposed by removal of the atlanto-occipital ligament. Stimulation of the medulla with a weak induction current produced marked stimulation of the respiratory center with a fall of blood pressure soon followed by a rise (fig. 5). When a current of 120 volts was allowed to flow through the medulla there was an immediate fall of blood pressure followed by a brief rise which soon fell to zero. Analysis of this curve (figs. 6 and 7) again shows a similarity to that produced in asphyxia.

thrown against the bony covering on the opposite side (*contre coup*). With the narrowing of the diameter of the skull caused by the zone of indentation, the brain may be nipped between the two sides of the cranium. It is possible that, as Duret suggested, the spinal fluid is forced down the narrow aqueduct of Sylvius, causing the lesions so frequently found in patients dying from injuries of the head. Thus it is that cases of injury of the head rarely come to autopsy without showing some gross lesion of the brain. Theoretically, however, concussion alone can kill, when death due to respiratory paralysis will be practically immediate, that is, will occur during the first ten minutes. Deaths occurring after the lapse of some hours are due to contusion, hemorrhages or the results accruing from these, such as edema.

Experimentally, however, it has never been demonstrated that concussion can be produced in animals without the accompaniment of gross lesion. The following experiments were devised in order to support the arguments advanced above. Trypan blue injected intravenously stains all the tissues, except those of the central nervous tissue, a deep blue. Should there be any inflammatory reaction of the central nervous tissue, or any gross lesion, that area will also take on the deep blue stain. This would appear a useful method of showing distinctly whether concussion can be produced without the presence of a gross lesion.

**EXPERIMENT 1.**—Two rabbits were used for this experiment. The first one was given general ether anesthesia. After trephining the skull, a fine needle was inserted into the cortex, the operation being conducted with aseptic surgical technic. A normal rabbit was then given a blow on the head of sufficient severity to cause unconsciousness of short duration. The blow was dealt with an instrument made by filling a thick rubber tube with lead shot, as such an instrument would be less likely to cause hemorrhages and contusions. The unconsciousness was presumed to be a condition analogous to concussion in man. In rabbits recovery from concussion is rapid. Within a minute the animals move about naturally and take food just as before. On each of the following three days, 20 cc. of a 1 per cent solution of trypan blue in physiologic sodium chloride was injected intravenously. On the fifth day the rabbits were killed and the brains hardened *in situ* by the injection of 50 cc. of a 10 per cent formaldehyde solution into the carotid artery. After forty-eight hours, the brains were removed and examined. In the rabbit in which the needle had pierced the cortex, a deep blue area in the cortex showed clearly where the needle had entered. This was surrounded by an area of pale blue to which, apparently, the inflammatory reaction had extended. The brain of the animal which had received the blow on the head, was without the stained area, neither were there any hemorrhages present, either subdural or scattered through the brain.

These experiments were repeated several times. Wherever the brain was damaged, the damaged area took up the stain and was colored a deep blue. The brains of animals which had suffered from concussion did not take the stain. Some of these animals showed subdural hemorrhages,

EXPERIMENT 4.—*Effect of weight falling on the dura.* (Modified experiments of Maassland and Saltikoff.)

A large dog was used under ether anesthesia. Two holes were trepanned in the skull, one on either side. Into one was screwed, in air-tight fashion, an instrument for recording the rise in intracranial pressure. The rubber membrane over the end of the inner tube rested directly on the brain. The other end of the tube was connected with a piston recorder. A long brass tube was screwed into the other hole, protected from resting on the dura by a brass flange. The dura on this side was not incised. A known weight could thus be allowed to fall down this tube on to the dura from any height, and the effects on the intracranial pressure were noted. When a weight of 350 Gm. was allowed to fall from a height of 6 inches, respiratory and vasomotor stimulation occurred (fig. 8). There was an immediate slowing of the pulse rate due to vagus stimulation. When

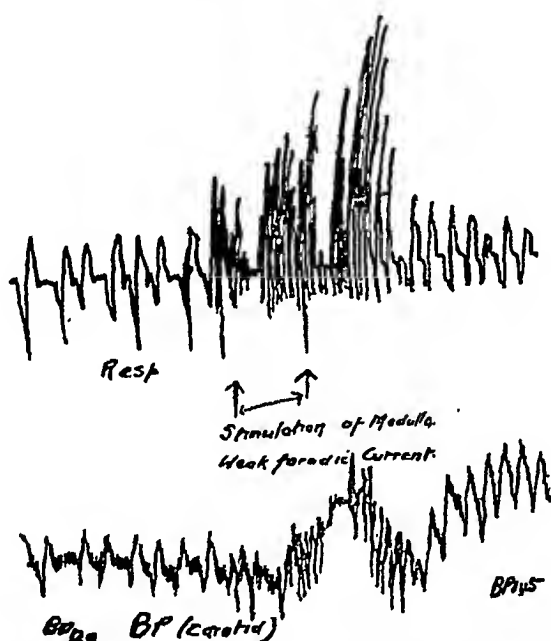


Fig. 5.—Effect of a weak induction current on the medulla. Note the marked stimulation of the bulbar centers.

the weight was allowed to drop from a height of 27 inches, there was immediate cessation of respiration, with a blood pressure curve again similar to that of asphyxia when the blood pressure had recovered from the immediate fall which occurred (fig. 9). The intracranial pressure showed an immediate rise and fall due to the movement of the brain (fig. 10). There soon followed a gradual rise, as shown by Cannon, which he ascribed to the edema resulting from the trauma to the brain tissue, though it may be in part due to resulting small hemorrhages.

EXPERIMENT 5.—*Direct mechanical effects on the medullary centers.*

Dogs were used under ether anesthesia. The mechanical effects were produced by injecting saline solution into the cisterna magna. When 10 cc. of physiologic sodium chloride at 37 C. were injected, marked stimulation of the bulbar centers occurred (fig. 11). When 12 cc. of this solution was forcibly injected in a similar manner, immediate paralysis of the respiratory center occurred. There was, first, a slight fall of blood pressure, soon followed by changes similar to those produced in asphyxia (fig. 12).

mild current is stimulating, that of severe ones, paralytic. A mechanical force, suddenly changing the pressures about the cells, may also disturb the equilibrium. The activity of cells depends on the equilibrium of the physicochemical state of the cells and of their environment.

The sudden violence with its rapid increase of pressure and quickly changing gravitational field might conceivably disturb this equilibrium and so cause temporary loss of function. Rahm has suggested that in response to the new gravitational field, the equilibrium of particles of different specific gravity will be disturbed. With this temporary disturbance of the physicochemical and gravitational equilibrium a loss of cell function might occur which, being generalized over the whole cerebrum, would cause the transient unconsciousness so typical of concussion. The medulla, being well protected by its position, would be saved from the greater part of this disturbance, and so paralysis of the medullary centers would be rare, as is actually the case.

Thus concussion readily lends itself to an etiologic explanation on purely mechanical grounds. Cerebral anemia is not involved. Contusions, though also mechanically produced, represent a more advanced lesion in that actual cell death is caused. Thus concussion is an immediate, transient, loss of consciousness with or without cell death, caused by the direct action of mechanical violence on the cells of the brain, and with no direct causative relations to cerebral anemia. It is distinct and separate from contusion or hemorrhages, whether minute or large and diffuse.

#### CONCLUSIONS

1. Concussion is immediate in onset, and tends to spontaneous recovery without sequelae.
2. Concussion must be sharply differentiated from all gross lesions, such as contusion and multiple petechial hemorrhages.
3. The most important symptom of concussion is complete unconsciousness with or without medullary symptoms.
4. Cerebral anemia is not a factor in the causation of concussion.
5. Concussion appears to be due to direct mechanical action on the cells which causes a disturbance of cell equilibrium and temporary loss of function.
6. The medullary effects are those of stimulation or paralysis of the respiratory, vagus and vasomotor centers.
7. The respiratory center is the first to be paralyzed. As this is usually a temporary paralysis, artificial respiration may save life.
8. Death from concussion is immediate and is due to respiratory paralysis with consequent asphyxia.



Weight 350 gms on  
dura from height of 6



Fig. 8.—Effect of a weight of 350 Gm. falling on the dura from a height of 6 inches. Note the respiratory and vasomotor centers show stimulation.

Weight 350 gms on dura  
from height of 27 in.

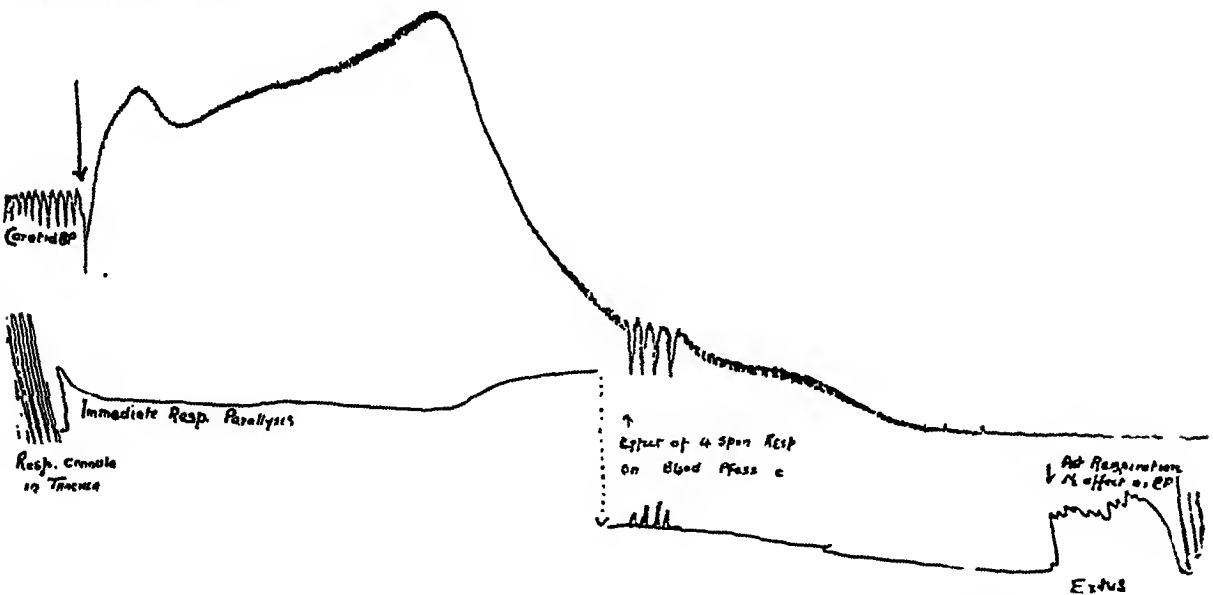


Fig. 9.—Effect of a weight of 350 Gm. falling on the dura from a height of 27 inches. Note immediate respiratory paralysis with a fall in blood pressure followed by a sharp rise, then a second slow fall to zero.



evagination consists at first only of entoderm, but it fuses later with mesoderm. The epithelial lining of the air passages springs from entoderm, while the basic structure springs from mesoderm. The trachea is the elongated stalk of the pulmonary system. At an early period, two dorsoventral ridges appear at the junction of the trachea with the esophagus. Interference of mesoderm with entoderm at this site would explain the causation of fistula.

#### REPORT OF CASE

*History.*—J. G., a girl, aged 5 hours, was admitted to the hospital on July 5, 1926, at 1 a. m. on the morning of its birth. The reason the child was admitted was that its mother, a graduate nurse, aged 24, had a retained placenta. This was her first pregnancy, and, except for the retained placenta, she had a normal delivery. There was no history of malformations or anomalies in the families of either parent. On the morning of admission the child became cyanotic at intervals, but these cyanotic attacks bore no relation to its attempts at feeding. It would not take nourishment, and there was considerable mucus in its throat which had to be aspirated at times. It passed a great deal of meconium. Attempts to feed the baby with a medicine dropper the following day were fruitless, and it was then fed by rectum.

*Physical Examination.*—The patient, a fairly well developed infant with slight icterus, who weighed 5 pounds and 14 ounces (2,665 Gm.), did not make any effort to cry when awakened or molested. Mucus was coming from its mouth. The temperature was normal. The results of general physical examination at this time were negative, except that a faint murmur was heard over the mitral area. From the history of the case and from the child's actions in the hospital, a congenital esophageal obstruction was suspected, and the infant was taken to the fluoroscopic room where a catheter was passed and a plate study made. The report by Dr. P. B. Mulligan was as follows:

In view of the clinical suspicion of a possible esophageal obstruction, a small amount of barium milk mixture was given the baby by mouth under fluoroscopic observation. The mixture descended only about as far as the suprasternal notch when it was regurgitated. Next a small catheter was passed through the nose into the esophagus; the catheter could be passed to about the level of the third rib anterior where it met with an obstruction; when force was exerted, the catheter coiled upon itself, forming a loop about 2 cm. in diameter. With the catheter in the esophagus some of the barium milk mixture was allowed to run into the catheter; this mixture collected in a pouchlike enlargement of the esophagus, the lower border of which was on a level with the third rib anterior; this enlargement was about 2.5 cm. wide and 3.5 cm. long; its borders were smooth in outline and extended posterior to the esophagus proper. Observation two hours later showed that none of the barium had entered the stomach; there was no barium in the lungs.

*Roentgen-ray Diagnosis:* Congenital atresia of the esophagus with congenital diverticulum. This patient, it was noted, had thirteen ribs on each side.

Immediately after this report was made, the child was prepared and taken to the operating room; under local anesthesia, the abdomen was opened through a high left rectus incision, and the stomach was exposed. It was impossible to pass a catheter through for bouginage because of the atresia of the esophagus. After a Weitzel gastrostomy had been performed, the child was returned to its room, and despite all efforts to save it, died that night from the shock of the operation, which was aggravated by its debilitated condition.

*Autopsy.*—Consent for partial autopsy was granted, and the following facts were noted: The child had a double uterus. The esophagus ended blindly in a

vagus escape when the stimulation of the vasomotor center becomes apparent. The results are the same whether the agency affecting the medulla is mechanical, electrical or nutritional. Cushing has shown that cerebral anemia produces stimulation of the vagus and vasomotor centers. All these agencies stimulate when of moderate degree. Stimulation, however, changes to inhibition, or paralysis, if the external agency is too severe. First, the respiratory center is paralyzed and a

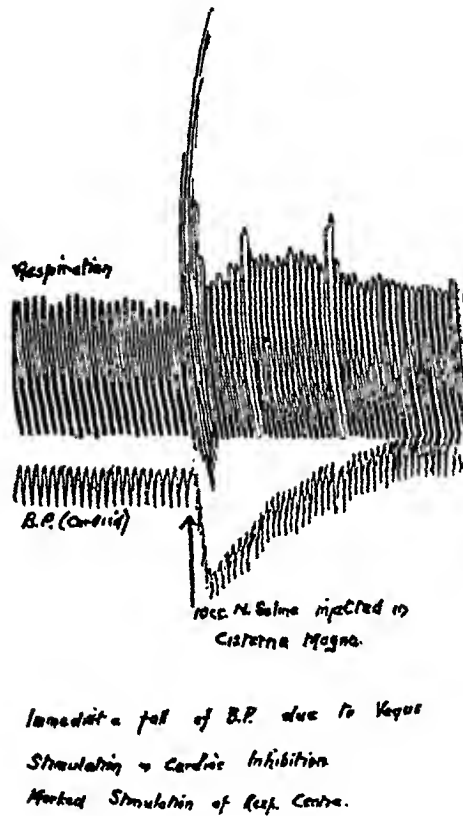


Fig. 11.—Effect of 10 cc. of physiologic sodium chloride injected into the cisterna magna. Note the immediate fall of blood pressure followed by a rise, also the respiratory stimulation.

condition of asphyxia exists. Maassland and Saltikoff were able to paralyze the vagus and vasomotor centers, together with the respiratory center, by placing heavy weights on the dura. This seems possible, though this effect has not been obtained in any of the numerous experiments carried out in the present research. The vasomotor center would appear to have an extraordinary resistance to violence.

diverticulum about 3 cm. below the pharynx. The lower portion of the esophagus ended blindly above and did not communicate with the diverticulum. A probe was passed from the stomach through the esophagus. It made its appearance in the trachea and emerged in the larynx. The cyanotic spells were explained on the basis of gastric secretion being eructated through the esophagus and by means of the fistula into the trachea.

#### CONCLUSIONS

1. Congenital tracheo-esophageal fistula is a rare diagnosis and is usually based on postmortem observations.
2. The diverticulum is easily demonstrated by the roentgen ray.
3. Tracheo-esophageal fistula must be considered as a cause for cyanosis in infants.
4. The development of this anomaly is based on embryologic considerations.

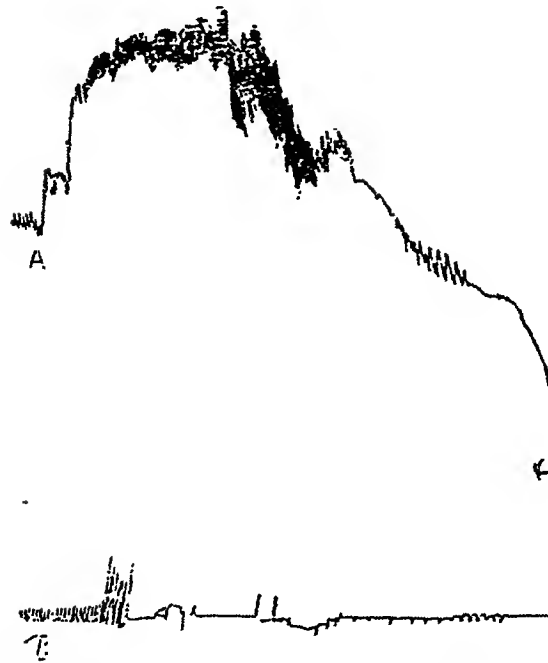


Fig. 13.—The effect of complete cerebral anemia on the respiratory, vasomotor, and vagus centers. (From Hill: Cerebral Circulation.)

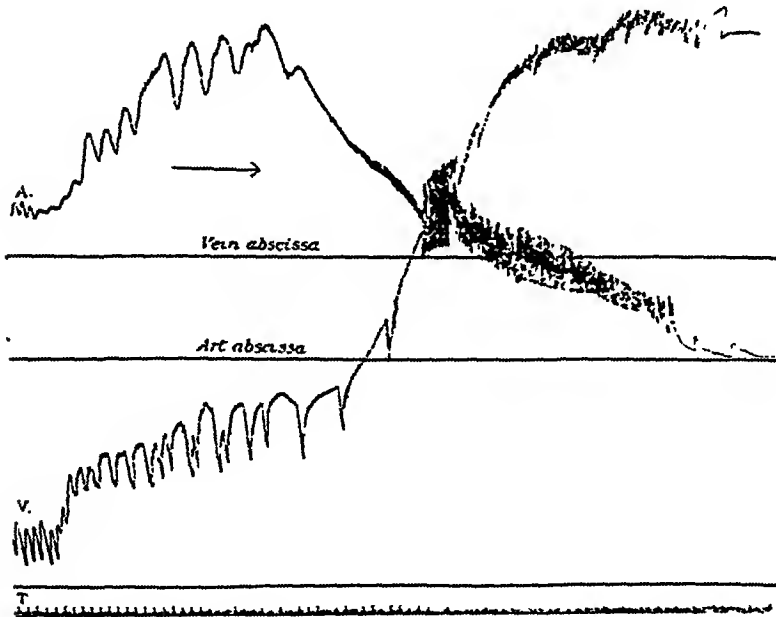


Fig. 14.—Effect of asphyxiation on blood pressure: when the venous pressure curve crosses the arterial pressure curve the pulse pressure increases, and the blood pressure remains constant for a few moments. This also occurs with respiratory paralysis, produced by blows, electricity currents and mechanical pressure. (From Halliburton: Textbook of Physiology.)

a Benedict spirometer with the graphic recording device. Arterial blood was obtained by puncture of the left ventricle or femoral artery; venous blood, by puncture of the right ventricle. The oxygen and carbon dioxide contents of the arterial and venous blood were determined. The circulatory minute volume was calculated from the Fick formula:

$$\frac{\text{Cc. O}_2 \text{ consumed per minute}}{\text{Amount O}_2 \text{ taken up in lungs by 1 cc. of blood}} = \frac{\text{Number of cc. of blood flowing through lungs per minute.}}{}$$

$p_{\text{H}}$  determinations were made by the method of Hastings and Sendroy.<sup>6</sup>

Ether anesthesia was then administered through an open cone, usually until the lid reflexes were abolished. The cardiac output was again determined. The method of Austin<sup>7</sup> was employed for determining the carbon dioxide content in the presence of ether.

In three of the five animals, the anesthetic was discontinued immediately after this determination, and alkali was injected intravenously. In the remaining two animals, alkali was injected while the anesthetic was continued, but to a lighter degree. Further determinations were made at variable intervals on the effects of alkali injection on cardiac output of dogs that were anesthetized previously and also on the output of the heart while the anesthetic was carried to approximately the same degree as that used in the control period. The alkali which was employed was normal sodium carbonate, and the amount varied from 40 to 100 cc.

## RESULTS

The animals remained quiet throughout the experiments. The changes which were encountered during the control anesthetic period (without alkali injection) have been described previously.<sup>1</sup> The most striking of these were the increased cardiac output, the decreased coefficient of utilization, the increased hydrogen ion concentration, the decreased carbon dioxide content and, in some instances, the decrease in the percentage saturation of the arterial blood.

The effects of injecting alkali immediately after discontinuing the anesthetic were noted in two animals (tables 4 and 5). The cardiac output was essentially the same as it had been during the anesthetic period. Harrison, Wilson and Blalock<sup>8</sup> have reported marked reduction in the cardiac output of normal dogs following the injection of alkali. It seems likely from the present experiments that the ether effect predominates over that of the alkali, and hence accounts for the failure of the cardiac output to decrease following the injection of alkali. The carbon dioxide content and the  $p_{\text{H}}$  were increased markedly by the administration of alkali.

6. Hastings and Sendroy: Studies of Acidosis; Colorimetric Determination of Blood  $p_{\text{H}}$  at Body Temperature Without Buffer Standards, *J. Biol. Chem.* **61**: 695 (Oct.) 1924.

7. Austin, J. H.: Estimation of Carbon Dioxide in Serum in Presence of Ether by Van Slyke Method, *J. Biol. Chem.* **61**:345 (Sept.) 1924.

8. Harrison, T. R.; Wilson, C. P., and Blalock, A.: *J. Clin. Investigation* **1**: 547 (Aug.) 1925.

dealing with the effect of immediate cerebral anemia produced by ligating the carotid and vertebral arteries, it is probable that the four arteries were not ligated simultaneously, but that the operation lasted a few seconds. Thus the impression was gained that cerebral anemia causes immediate unconsciousness (Hill <sup>35</sup>).

#### THE RELATION OF CONCUSSION TO MICROSCOPIC CONTUSION

I have already stated that a great controversy appears in the literature on the question of the relation of concussion to multiple contusions and petechial hemorrhages, many considering the conditions synonymous. If the conclusions reached previously are accepted, it is evident that a mechanical force paralyzing cell function need not necessarily be associated with cell death. It is evident that the generalized, transient, cortical paralysis seen in concussion is not the result of cell death, otherwise prompt recovery could not occur. Following contusion or petechial hemorrhage, an inflammatory reaction and repair process necessarily follow. The immediate symptoms would not, as in concussion, be the most severe, but rather the later symptoms would appear gradually with the development of reactionary edema and further cell death. The lesions would tend to cause a prolonged rise of the intracranial pressure; adjacent tissues would suffer from the edema, and so a protracted course with increasing severity of symptoms might be expected; further, destroyed neurons would not be replaced, but removed, and the lesion would be repaired with fibrous connective tissue. Thus sequelae of a more or less permanent character would result, unless the contusions were restricted to the silent areas. But prompt and complete recovery is generally accepted as one of the outstanding characteristics of concussion. Concussion and contusion can hardly be synonymous, as stated by Kocher.

Concussion can cause temporary paralysis of the respiratory center with prompt recovery. There could be no recovery if this damage were due to a contusion of the respiratory center. Contusion is synonymous with cell death. If the temporary paralysis of the respiratory center in concussion is prolonged beyond narrow limits death will occur. Thus death can occur in pure concussion. This explains why Kramer and Horsley,<sup>38</sup> and later Cannon,<sup>32</sup> by means of artificial respiration, resuscitated animals in which the respiratory center had been paralyzed by blows on the head.

Death, however, rarely occurs in cases of concussion without the added injury of numerous contusions and petechial hemorrhages. The medulla is well protected from injury by its position and only severe violence will cause immediate, prolonged, paralysis of the respiratory center. Ferrari showed how readily contusion of the cerebrum resulted from violence to the head. In response to the blow, the soft brain is

TABLE 3.—*The Effect on the Cardiac Output of (1) Ether Anesthesia and (2) Alkali and Ether*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. Minute, Ce.	Output per Bent, Ce.
6/23/26, 5 p. m.: Control study, ½ grain morphine	11	99	48	16.89	11.65	5.24	41.18	44.15	70.1	1,338	122	28
6/23/26, 5:50 p. m.: After ether for 15 minutes.....	11	98.6	155	17.25	10.11	7.14	34.43	39.56	62.7	877	80	5.7
6/27/26, 3 p. m.: After ether for 25 minutes.....	11	98	160	12.72	6.42	6.30	29.75	36.05	77.5	1,230	112	7.7
6/27/26, 1:35 p. m.: After alkali and during ether...	11	98	200	16.41	8.08	8.33	47.12	52.38	81.2	975	80	4.9

Protocol: 6/23/26: At 4:00 p. m., one half grain (0.03 Gm.) of morphine was given. At 5:00 p. m., control study was made; no food had been ingested for the previous twenty-four hours. At 5:35 p. m., ether anesthesia was begun. At 5:50 p. m., determinations were made; eye reflexes were abolished completely; the tracheal membranes were rather blue.

6/27/26: At 2:10 p. m., ether anesthesia was begun. At 3:00 p. m., determinations were made; the eye reflexes were abolished completely. At 3:30 p. m., under light anesthesia, 11 cc. of twice normal sodium carbonate was injected into the femoral vein. Specimens of blood were taken one hour later; eye reflexes were abolished at the time.

but they were not constant in position or degree and could not have been influential in the onset of the generalized cortical paralysis seen during concussion. These experiments demonstrate that concussion and contusion are not synonymous.

#### COMMENT

It was stated at the beginning of this article that it would be limited to an endeavor to establish the fundamental physiologic and pathologic basis of concussion. The main factors of confusion appear to lie in the difficulty of clearly differentiating concussion from lesions involving definite histologic and anatomic changes. Without general agreement or a definition of concussion, its scope and etiology, further work would appear futile. It has been shown, both by argument and experiment, that the term concussion should be used to denote the generalized, paralytic effects of an impact on the cortex and medulla, and should be distinguished from the term contusion, whether a gross or microscopic contusion is meant, and also from the term hemorrhage, whether reference is made to a diffuse or petechial hemorrhage. On the other hand, the term contusion should be limited to designate those cases in which destruction of cells can be assumed, and in which there is a tendency toward prolongation or aggravation of symptoms. It has been shown further that mechanical force, a stimulant when of small degree, can act like any other external factor, and paralyze cell function if of sufficient severity. The widely accepted hypothesis that cerebral anemia is the cause of cerebral concussion has been disproved by experiment and by argument. If the blood pressure tracing of complete cerebral anemia is compared with that of cessation of respiration by blows, it is seen that in the former the blood pressure rises immediately while the respiratory center shows deep respirations for seven or eight breaths (fig. 11). The paralysis of respiration due to a severe blow on the head is instantaneous, and there is a sharp drop in blood pressure due to vagus arrest of the heart (fig. 1). This evidence alone would cast doubt on the suggestion that concussion is due solely to cerebral anemia. The effects of concussion are immediate, while the paralyzing effects of cerebral anemia are not immediate but develop after five or more seconds. Thus it appears that concussion is the direct result of a sudden mechanical force on the central nervous tissue, which perhaps is the same conclusion at which Koch and Filehne arrived when they suggested that concussion was due to molecular disturbances or "ébranlement."

To endeavor to understand by what mechanism mechanical force can paralyze cell function, is to enter the realm of speculation. It is known that an electrical current which can produce a similar result, disturbs the equilibrium of the charged particles. The positively charged ions, for example, will be attracted toward the negative pole. The effect of a



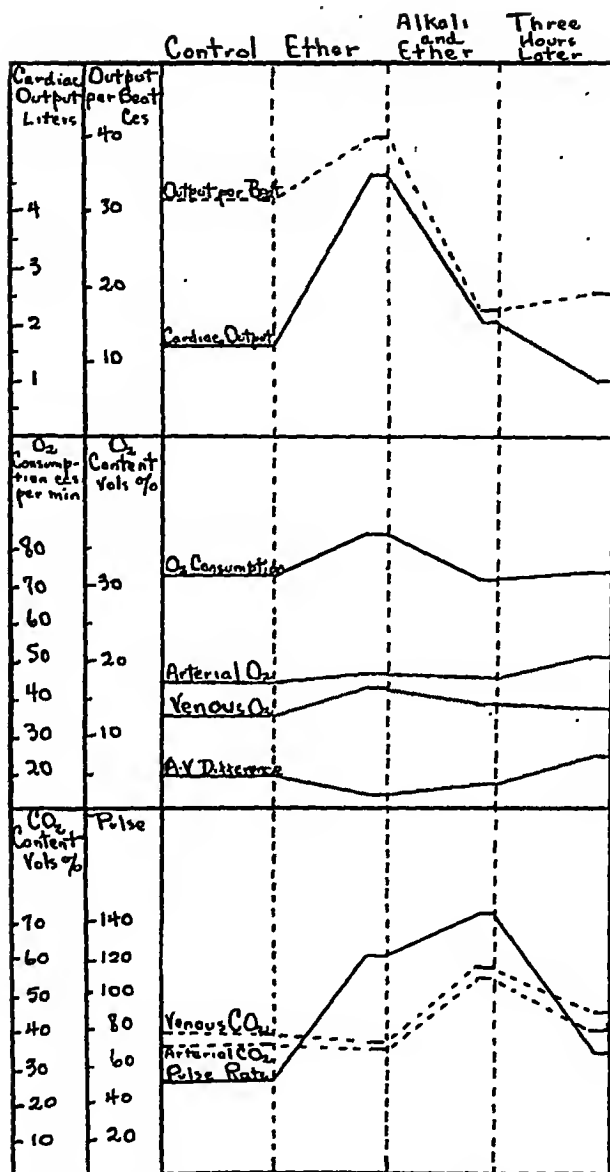


Chart 1.—The values in table 1 are charted in this figure. The increase in cardiac output during ether anesthesia was not so great following the injection of alkali as before, but it did not return to the control line. The decrease three hours later is shown. Alterations in the output per beat in this experiment parallel rather closely changes in the cardiac output. The arterial and oxygen contents approached each other during the anesthetic periods, but less closely after alkali was injected. The carbon dioxide content decreased with ether alone, and increased with alkali and ether.

In this and in the following charts, time relations are neglected.

# CONGENITAL ATRESIA OF THE ESOPHAGUS

## WITH ESOPHAGEAL DIVERTICULUM AND TRACHEO- ESOPHAGEAL FISTULA

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The first case report found in the literature according to McClellan and Elterich,<sup>1</sup> was cited by Thomas<sup>2</sup> and dated in 1696. Plass<sup>3</sup> reviewed the literature in 1917, and found 204 cases up to that year. Reynolds and Morrison<sup>4</sup> placed the total number of cases at 214 in 1921. In 1922, Steffen<sup>5</sup> and Willard<sup>6</sup> each reported another example of the anomaly. McClellan and Elterich<sup>1</sup> added another case in 1923. A diligent search of the literature reveals only one case since that time—a recent case reported by Flood.<sup>7</sup> This case, therefore, appears to be the 218th case on record. Reynolds and Morrison<sup>4</sup> state that only one such anomaly has appeared in sixteen years at the Bellevue Hospital. Stukowsky and Boran<sup>8</sup> found only one case in a hospital experience covering 50,000 cases. It has been pointed out recently by Brenneman that the apparent rarity is probably due to failure in diagnosis.

### EMBRYOLOGIC CONSIDERATIONS

The trachea and larynx are developed as an outgrowth from the entodermal alimentary canal. The first step in the development of the pulmonary system is a pouching of the ventral wall of the esophagus throughout its entire length. This ventral wall or groove deepens until its edges finally meet and fuse. In this manner the groove becomes a tube which is separated from the esophagus, beginning at the gastric end and extending toward the pharynx. This separation is not complete, however, until a bifurcation takes place—the bifurcation or pulmonary portion below. The tube above does not as yet separate. The

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1. McClellan, R. H., and Elterich, T. F.: Atresia of Esophagus with Tracheoesophageal Fistula, *Am. J. Dis. Child.* 26:373 (July) 1923.

2. Thomas: *Anatomy of Human Body, Epitomized*, London, 1703.

3. Plass, E. D.: *Johns Hopkins Hosp. Rep.* 18:259, 1919.

4. Reynolds, R. P., and Morrison, W. W.: Congenital Malformations of Esophagus, *Am. J. Dis. Child.* 21:339 (April) 1921.

5. Steffen, W. C. A.: *Arch. Pediat.* 38:823 (December) 1922.

6. Willard, H. G.: Congenital Atresia of Esophagus, *J. A. M. A.* 78:649 (March 4) 1922.

7. Flood, H. C.: *Atlantic M. J.* 29:538 (May) 1926.

8. Stukowsky, W. P., and Boran, A. A.: *Arch. f. Kinderh.* 58:119, 1912.

cent by volume higher than that obtained in the study of the effect of ether alone, and the same as that during the original control study without ether or alkali. The oxygen content of the venous blood was higher than that found in the control period without ether or alkali and

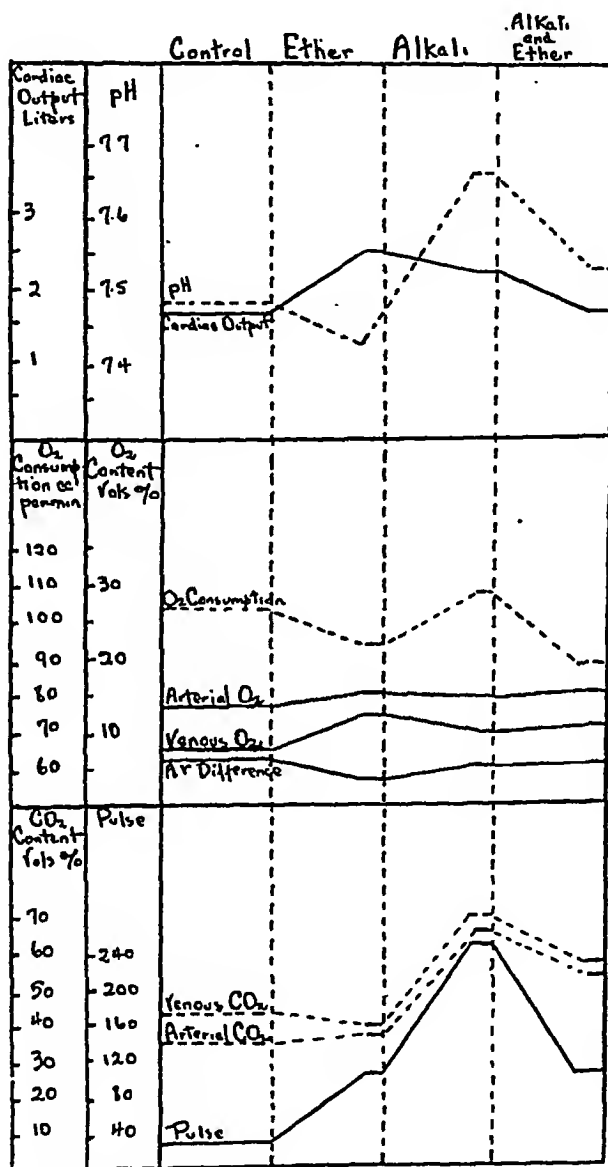


Chart 3. This chart shows that the cardiac output was increased markedly during ether anesthesia before alkali was injected and slightly increased afterward. The oxygen consumption being lower than the control figure in each instance, the increased output was counted for by the decrease in the coefficient of utilization. An acidosis was encountered only in the original anesthetic period. The values in table 5 are charted in this figure.

was lower than that during the original anesthetic period without alkali except for the experiment listed in table 3 in which the animal was deeply anesthetized. The coefficient of utilization was decreased, and the



Fig. 1.—A fine catheter inserted through the nose and ending in the esophageal diverticulum. The diverticulum is filled with barium. There are thirteen ribs on either side.



Fig. 2.—Posterior view of gross specimen showing the esophageal diverticulum above. The fibrous filaments replace the absence of esophagus and extending from the blind end of esophagus below to the esophageal diverticulum above. Insert shows a cross-section of the diverticulum and the fistula between trachea and esophagus.

cardiac output was increased over that during the control period without ether or alkali, except for the experiment listed in table 3, and in all instances the coefficient of utilization was increased and the cardiac output decreased as compared with the figures obtained during ether anesthesia without alkali (charts 1, 2, 3 and 4). A marked rise in both the arterial and venous carbon dioxide content occurred as compared with the figures for the other two periods, and the H-ion concentration was diminished. The percentage saturation of the arterial blood was not diminished as judged from the oxygen content of the arterial blood in all experiments and from determinations of the oxygen capacity in one experiment (table 5). There was a decrease in the cardiac output per beat in every instance.

In one experiment, the cardiac output was determined three hours after the anesthetic had been discontinued. The cardiac output was distinctly less than that during the previous studies. This drop was probably due to the depressing effect of alkali after the rise occasioned by the ether anesthetic had disappeared.

No measurements of the amount of ether which was used were made, but it seemed that less ether was required to anesthetize the animals after alkali had been injected, and that the period of recovery was prolonged.

It has been noted previously<sup>8</sup> that the H-ion concentration shows little tendency to return to normal after the injection of alkali in a normal animal. After the injection of acid, the return to normal was much more rapid. In the present experiments in which ether was administered after the injection of alkali, the  $p_H$  tended to return to normal much more rapidly. This is probably caused by the counter-acting effect of the acid metabolites.

#### COMMENT

The possible causes which might be responsible for the increased cardiac output of the heart during ether anesthesia have been mentioned and discussed previously.<sup>1</sup> Since it has been shown<sup>5</sup> that an acidosis, caused either by partial tracheal obstruction or by the injection of acid, produces an increase in the cardiac output, and that the injection of alkali causes a decrease, it was thought that the rôle of the H-ion concentration in the production of an increased output of the heart during anesthesia could be determined by converting the usual acidosis into an alkalosis by the injection of alkali.

The experiments reported here indicate that a great part but not all of the increase in the cardiac output of the heart may be caused by the increase in the H-ion concentration of the blood. In four experiments the percentage change in the cardiac output during ether anesthesia without alkali was  $+196$ ,  $+75$ ,  $+70$  and  $+45$ , while the

# CARDIAC OUTPUT IN THE DOG DURING ETHER ANESTHESIA

## II. THE EFFECT OF THE INJECTION OF ALKALI ON THE CARDIAC OUTPUT OF THE ANESTHETIZED DOG \*

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In a previous communication,<sup>1</sup> it has been shown that the cardiac output of the dog's heart is increased during an ether anesthetic. This change was associated with an increase in the hydrogen ion concentration of the blood. Boothby<sup>2</sup> first suggested that the H-ion concentration regulated the cardiac output of the heart. Douglas and Haldane<sup>3</sup> reached the same conclusion from studies on man. A similar view has been expressed by Means.<sup>4</sup> Harrison, Wilson and Blalock<sup>5</sup> found that the production of respiratory obstruction and the injection of acid were associated with an increase in the H-ion concentration of the blood and an increase in the cardiac output, and that the injection of alkali resulted in the reversal of these two functions. They concluded that the changes in the cardiac output of the heart were dependent on alterations in the H-ion concentration of the blood.

The object of the present study was to determine whether an alkalosis produced by the intravenous injection of alkali was accompanied by an increased cardiac output during ether anesthesia.

### METHOD

The method used was described in detail in the former paper.<sup>1</sup> In brief, it was as follows:

Dogs were anesthetized with morphine (0.04 to 0.08 Gm.). It has been shown that this drug has relatively little effect on the cardiac output of normal dogs. About an hour after the administration of morphine, control determinations were performed without ether or alkali. The oxygen consumption was determined by

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1. Blalock, A.: The Effect of Ether Anesthesia on the Cardiac Output, *Arch. Surg.* **14**:732 (March) 1927.

2. Boothby, W. M.: *Am. J. Physiol.* **37**:383, 1915.

3. Douglas, C. G., and Haldane, J. S.: Regulation of General Circulation Rate in Man, *J. Physiol.* **56**:69 (Feb.) 1922.

4. Means, J. H.: *Dyspnea Medicine* **3**:309 (Aug.) 1924.

5. Blalock, A.; Harrison, T. R., and Wilson, C. P.: Partial Tracheal Obstruction; and Experimental Study in the Effects on the Circulation and Respiration of Morphinated Dogs, *Arch. Surg.* **13**:81 (July) 1926; Effect of Changes in Hydrogen Ion Concentration on Blood Flow of Morphinated Dog. *J. Clin. Investigation* **1**:547 (Aug.) 1925.

dioxide content was caused by the alkali injection. Since there was an elevation of the cardiac output in each instance, it does not seem plausible to ascribe this effect to changes in the carbon dioxide content. It seems a likely assumption that the greater part of the increase in cardiac output during ether anesthesia is caused by an increase in the H-ion concentration, as the elevation was much less marked after the injection of alkali. In order to explain the increased output when the H-ion concentration is not increased, it is necessary to assume that there is some direct stimulating action of ether itself. Unless ether has a peculiar action on the peripheral vessels, it is likely that the vasodilation which occurs in acidosis disappears after alkali is injected. Despite the experimental evidence that ether decreases the output of the isolated heart, it is possible that the intact heart may be stimulated directly by ether to pump a greater quantity of blood.

The therapeutic administration of alkalis previous to operations under general anesthesia has been suggested and practiced by many physicians. MacNider<sup>14</sup> recommends the giving of alkalis to prevent the development of anuria, which may occur after a marked reduction in the alkali reserve of the blood. Gwathmey and Tibbetts<sup>15</sup> suggest the giving of sodium bicarbonate previous to a general anesthetic to combat acidosis. Richardson<sup>16</sup> emphasizes the importance of giving alkalis before long operations. However, Meyers and Booher<sup>17</sup> caution against the uncontrolled administration of alkali. They report uncompensated alkalosis following the administration of sodium bicarbonate, following roentgen-ray treatment, after continued vomiting and following prolonged elevations of temperature. Koehler<sup>18</sup> found that the H-ion concentration is decreased during an acute clinical fever. Fever and vomiting are common sequelae of anesthesia, and from this point of view, one should be cautious regarding the indiscriminate administration of alkali. Moreover, evidence that acidosis of short duration per se exerts a harmful effect is lacking. A still more valid objection to the use of alkali lies in the fact that the length and depth of the anesthesia and, consequently, the degree of acidosis, cannot be estimated previous to the operation. Hence, the amount of alkali needed cannot be known

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14. MacNider, W. de B.: Anurias Occurring in Normal Animals During Use of General Anesthetics, *J. Pharm. & Exper. Therap.* **15**:249 (June) 1920.

15. Gwathmey, J. T., and Tibbetts, E. S.: A Preliminary Report on Laboratory Experiments to Determine Value of Certain Agents in Connection with Surgical Operations, *M. Rec.* **98**:1021 (Dec. 18) 1920.

16. Richardson, F. L.: Heart Lesions in Anesthesia, *Am. J. Surg.* (anesthesia supplement) **33**:109 (Oct.) 1919.

17. Meyers, V. C., and Booher, L. E.: Some Variations in Acid-Base Balance of Blood in Disease, *J. Biol. Chem.* **59**:699 (April) 1924.

18. Koehler, A. E.: Acid-Base Equilibrium; Clinical Studies in Alkalosis, *Arch. Int. Med.* **31**:590 (April) 1923.

TABLE 1.—The Effect on the Cardiac Output of (1) Ether Anesthesia and (2) Alkali and Ether

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Cent.
6/18/20, 3:30 p. m.: Control study, 1 grain morphine..	10	101.6	50	16.00	12.31	4.59	36.18	38.99	74.8	1,611	161	32
5:20 p. m.: After 20 minutes anesthetic.....	10	102	120	17.61	15.26	1.78	37.78	36.04	81.9	4,770	477	40
6:20 p. m.: 20 minutes after 4 cc. twice normal sodium carbonate intravenously..	10	102.2	110	17.05	12.78	3.56	52.93	55.71	70.11	1,069	107	14
ing alkali and ether.....	10	101	60	19.54	13.49	6.76	38.40	43.82	73.8	1,002	100	18

Protocol: 0.48-20: At 2:45 p. m., one grain (0.06 Gm.) of morphine was given. At 3:00 p. m., tracheotomy was performed. At 3:30 p. m., control determinations were made. At 4:10 p. m., ether anesthesia was begun. At 5:00 p. m., eye reflexes were barely obtainable; specimens of blood were drawn. At 5:30 p. m., the dog was still anesthetized; it was given 40 cc. of twice normal sodium carbonate. At 5:50 p. m., eye reflexes were barely obtainable; specimens of blood were drawn. At 6:00 p. m., three and a half hours after injection of alkali, and three hours after the ether was discontinued, the dog was walking around and looked well. Determinations were made without an anesthetic.

TABLE 2.—The Effect on the Cardiac Output of (1) Ether Anesthesia and (2) Alkali and Ether

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Cent.
6/19/20, 12:10 p. m.: Control study, 3/4 grain morphine	9.7	100	68	22.12	12.61	9.78	36.61	42.17	73.8	755	78	11
6/19/20, 1:15 p. m.: Control study.....	9.7	102	18	22.54	13.12	9.42	37.42	43.12	73.8	783	81	16
4:05 p. m.: Anesthesia for 45 minutes.....	9.7	101	160	23.11	17.65	5.49	23.32	26.71	73.8	1,311	130	8.4
5:10 p. m.: After ether and carbonate.....	9.7	101	100	20.51	14.21	7.97	42.89	47.19	73.8	1,015	101	5.3

Protocol: 6/19/20: At 11:30 a. m., three fourths grain (0.01 Gm.) of morphine was given. At 12:10 p. m., control studies were made. At 1:15 p. m., second control studies were made. At 3:30 p. m., anesthetic was begun. The dog stopped breathing once, but eye reflexes were present at 4:00 p. m., when specimens of blood were taken. Animal well relaxed at time. At 4:25 p. m., it was given 20 cc. of twice normal sodium carbonate. At 5:20 p. m., ether again was administered. At 5:40 p. m., after ether for twenty minutes, specimens of blood were taken; eye reflexes were easily obtained. The animal was relaxed.



# A REVIEW OF UROLOGIC SURGERY

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LOS ANGELES

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LOS ANGELES

(Concluded from page 792)

## URETER

*Ureteral Transplantation.*—Smitten<sup>25</sup> compiled 318 cases of implantation of the ureters into the intestine, not including the Maydl type of operation. Two hundred and twenty-two were in women, and forty-nine in men. The statistics of the operations were as follows: fistula of the bladder, 156 cases, with death in thirty-four (21.8 per cent); anomalous conditions, fifty-eight cases, with death in eighteen (31 per cent); malignant tumors, ninety-eight cases, with death in sixty-one (63 per cent); inflammatory processes, four cases, with death in three (75 per cent). Of the total number of patients, 116 died and 200 recovered; in two cases the result was not known. Thirty patients died from peritonitis, twenty-one from urinary infection, five from pneumonia and three from tuberculosis. The late results from six months to ten years were known in seventy-one cases. In six of these death was caused by renal insufficiency; in three by recurrence of the original condition, and in two, by intercurrent disease. After the first operations, there usually was considerable inflammatory reaction in the rectum that at times either caused perforative peritonitis or ascending infection in the kidney. Suture infection was observed in ten cases.

Bégouin,<sup>26</sup> reviewing his cases of ureterocystostomy, states that in cases of accidental or voluntary section of the ureter this operation, which is simple and only requires a few minutes, adds little to the

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25. Smitten, A. T.: Ueber die Einpflanzung der Ureteren in den Darm, *Ztschr. f. urol. Chir.* 19:219-220, 1926.

26. Bégouin, P.: De l'insuffisance fonctionnelle du rein apres l'ureterocystostomie, *Arch. franco-belges de chir.* 29:81-85 (Feb.) 1926.

Weight, Kg.	Temper- ature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio- venous Difference	Arterial Carbon Dioxide	Venous Carbon Dioxide
12.7	99.4						

Output of (1) Ether Anesthesia and (2) Alkali and Ether									
Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-Venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Output per Kg. per Minute
6/28/24, 3 p. m.; Control study, 1 grain morphine	13.3	99.4	50	15.58	10.11	5.47	35.78	40.37	1.003
3:55 p. m.; After 15 minutes anesthesia	13.3	99	120	15.58	12.72	2.86	35.37	37.53	1.20
4:20 p. m.; 15 minutes after sodium carbonate	13.3	98.5	100	15.22	11.59	3.63	40.55	53.73	2.06
5:05 p. m.; 35 minutes after alkali	13.3	97	115	15.22	12.13	3.09	40.08	51.17	2.978
after ether started.....	13.3								

Practical: 6/28/29. At 2:00 p. m., one grain (0.06 Gm.) of morphine was given, and ether anesthesia was begun; determinations were made fifteen minutes after alkali was given, and he was conscious.

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The Cardiac Output of (1) Ether Anesthesia and (2) Alkali and Ether									
Date	Weight, Kg.	Temp., °C.	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	<i>pu</i>
9/29/24, Control	13	37.5	92	13.79	7.61	6.18	35.61	42.50	7.47
1:30 p. m.; After 75 minutes ether	13	37.5	100	11.87	11.00	3.81	36.45	38.88	7.42
2:35 p. m.; After 104 minutes ether	13	37.5	100	11.27	9.51	4.76	61.54	63.31	7.05
4:10 p. m.; After 150 minutes ether	13	37.5	100	11.57	9.61	4.91	53.10	57.78	7.52

Protocol: 9/29/24: At 11:00 a. m., one grain (0.06 Gm.) of morphine was given. At 1:50 p. m., ether anesthesia was begun. At 1:50 p. m., determinations were made with the dog under ether; the dog was quiet and control studies were made. At 2:20 p. m., the administration of ether was begun. At 2:30 p. m., the dog was relaxed. At 4:10 p. m., studies were made. At 4:45 p. m., the dog was quiet and control studies were made.

132	17
the eye reflexes were abolished and control study was made. At 12:15 p. m., attempts to show the effect of alkali were made; no ether was administered; the dog unanesthetized; the eye reflexes were abolished	

ingrowth of pelvic epithelium; (5) the formation of small diverticula by the action of the irritant urine when large openings have allowed the urine to reach far into the tissue, and (6) the replacement of the normal fat and connective tissue about the pelvis by dense fibrous connective tissue.

The changes in the kidney proper consist of: (1) exceptionally, focal necrosis of the epithelium with leukocytic infiltration; (2) exceptionally (only once in this series), infarction of the kidney, and (3) necrosis of the tubules of the papilla, exceptionally, with necrosis of the entire papilla.

The relation of these experiments to the pathology of pyelitis in man can be summarized as follows: (1) certain hemorrhages (evidence of which is found after death) in the pelvis of the kidney following obstruction of the ureters may be attributed to pressure and not necessarily to infection; (2) the formation of diverticula of the pelvis might give rise to sterile pyuria that persists for a long time; (3) the products of acute inflammation can be removed so rapidly as to leave practically no trace after a period of fourteen days, and (4) the necessity of controlling results in experiments on the injection of bacteria into the pelvis, when the ureter is obstructed, is evident since the presence or absence of infection makes no marked difference in the gross and microscopic appearance of hydronephrotic kidneys during the first twenty-four hours.

*Calculi.*—Hourtoule<sup>28</sup> reports the case of a married woman, aged 22, who had suffered attacks of colic from ureteral stone for seven years. A small hard mass, 2 cm. in diameter, was felt in the left culdesac; roentgenologic examination proved this to be a stone. The left kidney, which was found to be almost functionless at cystoscopy, also contained stones. The patient became pregnant and gave birth normally to a healthy child. After pregnancy the attacks of colic returned, and this time were accompanied by fever. At operation a voluminous left hydronephrotic kidney was removed. The ureteral stone was left in place. Two years later, she was perfectly well; the ureteral stone had not caused any trouble.

Bunipus and Scholl<sup>29</sup> report a series of 880 cases of ureteral stone treated at the Mayo Clinic. Of these, 640 were removed surgically and 240 were removed by cystoscopic manipulation during the later years. Six hundred and forty-eight operations were performed in 640 cases, eight of which were bilateral. The following types of operation were performed: ureterolithotomy, extraperitoneal, 522; pelviolithotomy,

28. Hourtoule, V.: A propos d'un calcul de l'uretère. *J. d'urol. méd. et chir.* 20:318-319, 1925.

29. Bunipus, H. C., Jr., and Scholl, A. J.: Ureteral Stones, *Surg. Clin. N. Amer.* 5:813-827 (June) 1925.

Determinations made during an ether anesthetic following the injection of alkali as contrasted with those obtained during both the original control period without ether or alkali and the anesthetic period without alkali injection reveal the following changes: The temperature remained

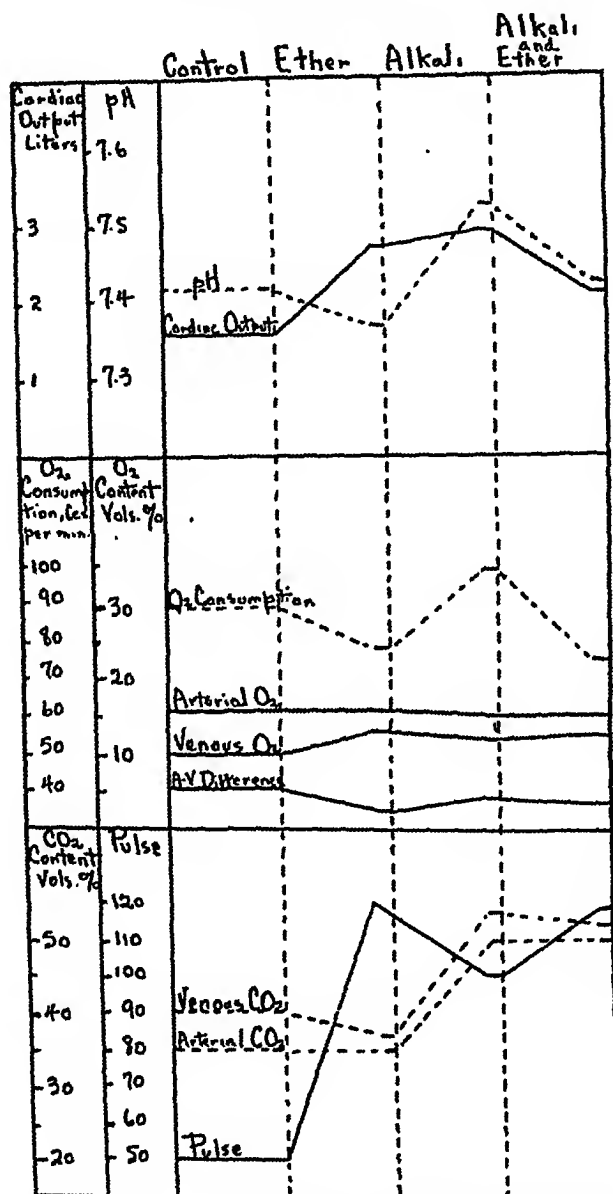


Chart 2.—The points to be noted include the less marked elevation in cardiac output during ether anesthesia following the injection of alkali, the rise in the venous oxygen content while the arterial oxygen content remained stationary and the elevation of the carbon dioxide content. The values in table 4 are charted in this figure.

about the same or fell slightly, and the pulse rate was elevated definitely in four of the five experiments. The oxygen consumption was usually slightly decreased. The oxygen content of the arterial blood remained the same in four instances: in the remaining experiment it was 4 per

four of the 648 stones removed by surgical methods were at the ureterorenal juncture, seventy-one in the lumbar segment, forty-one in the middle or iliac segment, eleven at the iliac crest, 311 in the lower third, eighty-eight at the ureterovesical juncture, and thirty-six were intramural.

The kidney was removed in eighty-one cases. In forty-eight cases the ureter also was removed, in most instances completely. In most of these the kidney had been partially or completely destroyed as a result of ureteral obstruction. In a few cases there were also stones in the kidney. In most of the cases in which nephrectomy or nephroureterectomy was performed, the kidney was exposed through a posterolateral incision. If the stone could then be reached, the kidney and segment of ureter were removed. If the stone was in the middle or lower third and the ureter dilated and the stone impacted, the vascular pedicle was cut and ligated, and the kidney left hanging from the anterior angle of the wound. The patient was then turned over and an anterior rectus incision made, through which the ureter was isolated and cut below the stone. The ureter was freed as far as the point reached from the posterior incision and then drawn through the posterior wound while still attached to the kidney. It is usually desirable to leave a long strand of catgut or silk fastened to the retreating ureter so that the lower end of the ureter may be recovered if it does not readily pass through into the area of the posterior incision.

*Tumor.*—Stewart,<sup>30</sup> reviewing the literature from 1922 (when Aschner had compiled forty-seven cases of primary tumor of the ureter) found five other cases recorded and reports an additional case. These rare tumors occur most frequently during the sixth decade of life.

Calculus is not a common predisposing factor; when present it is generally associated with malignant forms of tumor. Pathologically, these tumors usually are papillary in type and many show the structure of benign papilloma, in which case they may be multiple or diffuse. There is a decided tendency toward malignancy: papillary carcinoma, medullary carcinoma and squamous epithelioma occur. Sarcoma is rare. Any portion of the ureter may be involved, although there is evidently a predilection toward either the upper or the lower extremity.

The symptoms produced are not pathognomonic of the disease, and are the same as those engendered by renal neoplasms, namely, hematuria, pain and sometimes renal enlargement due to the tumor obstructing the ureter and causing hydronephrosis. Accurate diagnosis usually is difficult, but considerable aid is obtained from the employment of ureteral catheterization and pyelo-ureterography. It is important to locate the

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30. Stewart, R. L.: Primary Tumors of the Ureter, *Brit. J. Surg.* **13**:667-682 (April) 1926.

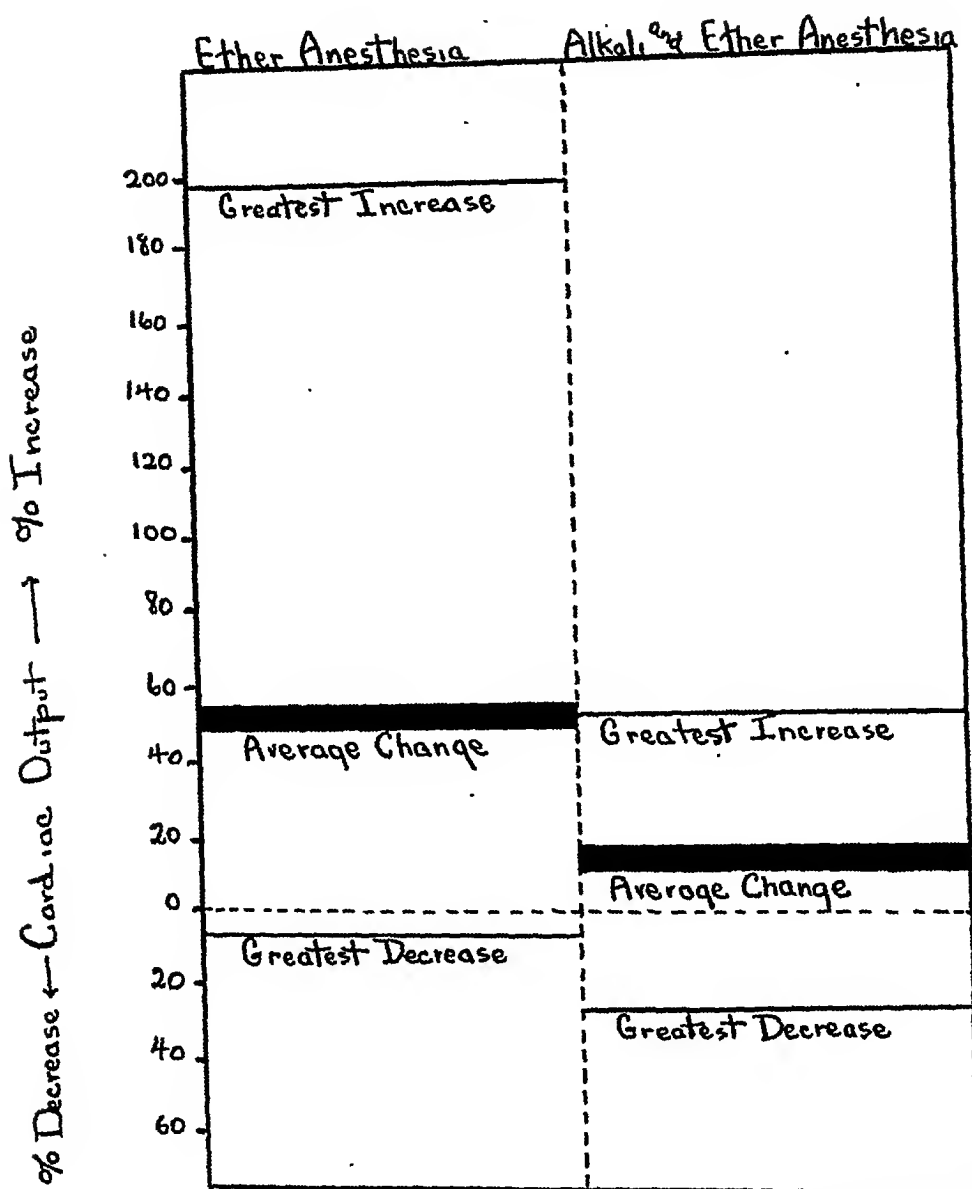


Chart 4.—The percentage change in the cardiac output, under the heading "Ether Anesthesia," was obtained by comparing the figure for the cardiac output during ether anesthesia with that during the control period. The percentage change in the cardiac output under the heading "Alkali and Ether Anesthesia" was obtained by comparing the figure for the cardiac output during ether anesthesia following the injection of alkali with that obtained during the same original control period. The average change is computed from all of the experiments.

It is to be noted that the average increase in cardiac output during ether anesthesia without alkali injection corresponds to the highest figure obtained during ether anesthesia after alkali injection.

development of diverticula is most common in association with such obstructions of the urinary tract as prostatitis and prostatic hypertrophy afford. With the enlargement of the diverticulum the bladder itself becomes filled with each relaxation of its neck. Thus, marked detrusor hypertrophy develops. The contraction of the bladder is partly used in further distending the diverticulum so that a condition exists somewhat analogous to valvular insufficiency in the heart. Lurz has shown by experiments, with one catheter in the diverticulum and another in the bladder, that the pressure according to manometric readings is less in the diverticulum than in the bladder itself.

Symptomatically, the relative youth of the patient, lack of frequency at night, longer duration of symptoms, change in the degree of difficulty of urination from time to time, slowness of the emptying of the bladder with absence of stricture, prostatic hypertrophy or disease of the spinal cord, the occurrence of stone shadows in the roentgenogram of the bladder, when these stones are not demonstrated by cystoscopy, residual urine and infection serve to differentiate the condition from prostatic disease. In some cases in which the diverticulum is attached to the rectum, defecation is painful or the bladder can be emptied only on sitting as at defecation. Hematuria may occur at times or there may be ureteral colic from compression of the ureteral ostia.

The diagnosis is based on urologic study such as cystoscopy, and roentgen-ray studies of the bladder, filled with an opaque medium (cystography), or after an opaque catheter has been inserted into the diverticular orifice. Lurz reviews the technic and precautions necessary with these procedures.

The treatment of the condition usually advised is radical surgical excision. A few urologists advocate drainage of the diverticulum by indwelling catheters and lavage of the sac with silver preparations, but these are in the minority. The utmost care is urged in the study of the urinary function before surgical treatment is undertaken. Differential tests of function, study of retention of blood urea, and the investigation of the urinary tract for infection, must be gone over carefully. Any gross infection should be treated and ameliorated, if possible. The various operative procedures are outlined. Lurz prefers the suprapubic transverse incision after elevation of the pelvis. The disadvantages of Voelcker's parasacral route are brought out. The extraperitoneal, extravescical operation in most cases is ideal. The next best procedure is the extirpation of the diverticulum from within the bladder. The dangers to rectum or ureters from operative procedures, and the precautionary measures to protect these structures (such as placing catheters in ureters before operation or injecting indigocarmin), are emphasized. At times it is necessary to transplant the ureters. Geraghty's resection of the mucosa from the diverticular neck with closure and extravescical drainage of the diverticular sac is cited.

corresponding figures during ether anesthesia following the injection of alkali were +22, +32, +49, and +3, respectively. In the experiment in which the degree of anesthesia was deep, the decrease in the cardiac output during the control anesthetic period was 8 per cent, while during the anesthetic period following the injection of alkali the decrease was 30 per cent.

Henderson<sup>9</sup> and Douglas and Haldane<sup>10</sup> found a decrease in cardiac output with excessive artificial respiration. Grant and Goldman<sup>11</sup> found that this was associated with an alkalosis in which the carbon dioxide tension of the blood was diminished. Alkalosis was produced in the present experiments by the injection of alkali and was associated with an increase in the carbon dioxide content, without any appreciable change in the carbon dioxide tension, and a figure for cardiac output which was less than that for the anesthetic period, but which remained elevated over that during the control period without ether or alkali. Henderson<sup>12</sup> has emphasized the importance of carbon dioxide pressure in the regulation of venous pressure, and hence the diastolic filling and cardiac output of the heart.

Other experiments<sup>13</sup> have demonstrated an increase in the output of the heart during severe anoxemia. The present report (tables 1 to 5) does not suggest this factor as the probable one in causing the increased cardiac output of the heart during ether anesthesia, as evidence of a decrease in the percentage saturation of the arterial blood was not found. The oxygen capacity of the arterial blood was determined in only one experiment, but the arterial oxygen content in all experiments showed practically no variation from that of the control period.

The studies of the effect of ether anesthesia on the cardiac output suggested that the increased output was caused by an increase in the H-ion concentration, by anoxemia, by the direct action of ether itself or by a combination of these factors. It is seen in this report that the output of the heart may remain somewhat elevated in the presence of a  $p_{\text{H}}$  which is on the alkaline side and in the absence of a decrease in the percentage saturation of the arterial blood. It is known that ether anesthesia in some instances, causes a decrease in the percentage saturation of arterial blood, but it was not encountered in these experiments. The studies which were made on the effect of ether anesthesia alone were associated with a decrease in the carbon dioxide content of the blood, while in the present experiments the high carbon

9. Henderson, Y.: *Am. J. Physiol.* **21**:126, 1908.

10. Douglas, C. G., and Haldane, J. S.: *J. Physiol.* **41**:69, 1922.

11. Grant, S. B., and Goldman, A.: *Am. J. Physiol.* **52**:209, 1920.

12. Henderson, Y.: *Volume Changes of Heart*, *Physiological Rev.* **3**:165 (April) 1923.

13. Harrison, T. R., and Blalock, A. In press.



vulcanite, with a metallic lining. This lining only comes to the surface at the edge of the window situated below the beak; elsewhere it is insulated from the urethra by the bakelite covering.

The punch is introduced with an obturator in position, and, to facilitate its insertion in difficult cases, a pliable bougie guide may be attached to the beak by means of a screw. When it is in position the obturator is withdrawn, and a system consisting of a telescope, a lamp and inlet and outlet tubes for irrigation is substituted, thus converting the instrument into a posterior urethroscope of the Gueringe type. Under guidance of the eye, the punch is now withdrawn until the bar is seen to engage the window. Once it is in position, the instrument is held firmly and pressure is exerted on the bar by slightly raising the proximal end. Connection is then made with the source of diathermy current. When the current is turned on, the inner metallic layer of the sheath immediately becomes a urethral electrode but, owing to the insulation conferred by the bakelite covering, the only point of contact with the urethra is the edge of the window engaging the bar. From this edge a line of coagulation can be observed to spread within ten or fifteen seconds; this whitens the whole area of prostate engaged. By maintaining continuous irrigation, the process of diathermy can be carried out under complete ocular control, the current being turned off when it is judged that a sufficient depth of tissue has been destroyed.

In order to remove the wedge of destroyed tissue, and thus obtain immediate benefit without waiting for the separation of sloughs, the telescope and lighting system is withdrawn and an inner tube, resembling that used in the Young punch, is inserted. By pushing this home and giving it at the same time a slight rotary movement, a core of destroyed tissue, about 2 cm. in length and 0.5 cm. in diameter, may be removed. This does not, however, constitute the whole amount of prostatic tissue destroyed by the operation, the full benefit of which will be obtained later when the sloughs have separated. The telescope and lighting system may then be reintroduced, the area of operation inspected, and a decision made as to whether or not any further fulguration is required. If the operator is satisfied with the amount of tissue dealt with, the bladder is emptied, the obturator inserted and the instrument withdrawn.

The diathermy punch has definite advantages over any similar instrument yet evolved. The operation is not a blind proceeding like Bottini's, but is done under full ocular control. It has an advantage over Young's operation in that it eliminates the risk of hemorrhage, and it allows the easy removal of greater quantities of prostatic tissue, the subsequent sloughing of the diathermy area widening still further the channel dug by the punch.

The type of case in which the diathermy punch can be employed most conveniently is that in which there is a "bar" obstructing the vesical outlet. It may also be used in cases of moderate enlargement in

unless repeated determinations of the alkali reserve and the H-ion concentration are made during the operation, and this is impracticable. The evidence presented in this paper suggests that alkali may be of value in preventing overstrain of the heart, but it is possible that such treatment may have other untoward effects.

#### SUMMARY

The cardiac output of the heart of the morphinized dog has been determined during ether anesthesia both with and without the injection of alkali. The changes in pulse rate, temperature readings, oxygen consumption, arterial oxygen, venous oxygen, arterial carbon dioxide, venous carbon dioxide, H-ion concentration and cardiac output have been observed. The following statements are believed to be true for the dog:

1. The percentage increase in the cardiac output of the anesthetized dog is reduced by the injection of alkali.
2. The increase in cardiac output persists during ether anesthesia in the presence of an alkaline  $p_H$ , but to a lesser degree than when acidosis is present.
3. The increase in cardiac output is not dependent on anoxemia.
4. The carbon dioxide content is elevated during ether anesthesia following the injection of alkali, whereas it is lower than normal during ether anesthesia without alkali injection.
5. The alteration in the cardiac output of the heart cannot be attributed entirely to the effect of changes in the hydrogen ion concentration of the blood, and that there is some direct stimulating action by ether must be assumed.

The objections to the use of alkali have been discussed. Without further information, the routine administration of alkali before operations does not seem advisable.

higher when the risk was supposed to be moderate, and the usual catheter drainage and other preliminary medication was not given, than when the risk was presumed to be grave and a stringent preoperative regimen was consequently instituted. At the present time all patients are given preliminary treatment, as mentioned, the majority of them being put on catheter drainage.

After enucleation of the prostate under vision, the capsule is sutured, a sound is passed through the penis into the open bladder, and the tube of the Pilcher bag is then drawn out with it through the urethra. The bag is distended with water so that it impinges on the vesical neck. The pressure required is from 60 mm. of mercury (about 60 cc. of water) to 140 mm. of mercury (about 180 cc. of water). A silken cord threaded through the tube of the bag and attached to the base rather than the apex of the bag, is attached to a Hamer tripod under moderate tension, just enough to hold the bag in place and control hemostasis without unnecessarily stretching the prostatic capsule. By this means, the pressure is brought from the base of the bag toward the prostatic bed rather than pulled into the prostatic bed by elastic traction on the urethral tube.

Suprapubic drainage is maintained by placing a 30 F. catheter in the bladder, which is closely sutured around this catheter and around the vesical portion of the tube of the Pilcher bag which extends through the bladder and abdominal wall. Through this suprapubic tube of the bag the water is released in about sixteen hours. If any bleeding occurs, the bag is refilled for a further period. If no bleeding occurs, the bag and vesical catheter are all removed suprapubically eight hours later. As the bag is removed a 16 F catheter, attached to the urethral portion of the tube, is drawn in as an indwelling catheter. Immediate urethral drainage is thus established and prolonged, and messy suprapubic drainage is avoided.

[ED. NOTE.—No one who has seen Hunt work can fail to be impressed by the effectiveness of the method described in his hands. It seems ideal, as does the whole one-stage procedure, and almost perfect from the surgical standpoint. During the last few years the results of suprapubic prostatectomy have equalled in almost every way the low mortality rates of the perineal operation. Certainly, the method described by Hunt fulfils all the requirements of surgical simplicity and efficiency and will be welcomed by those general surgeons and urologists who have not had satisfactory results in the control of hemorrhage from the prostatic bed after operation. The use of a hydrostatic-pressure bag does not appeal to all surgeons as entirely a surgical procedure. Complete hemostasis at the time of operation, together with gauze packing, works effectively in preventing bleeding either directly or some time after operation.

gravity of the operation. Of six of Bégouin's patients, seen from six months to three years after operation, none presented normal ureteral permeability or good renal function. In two cases there was complete obliteration of the implanted ureter; in one, stricture at its end had caused hydronephrosis, and in another there was a large orifice, permitting marked ureteral reflux. In a fifth case pyelonephritis necessitated nephrectomy. The last case, although the orifice was apparently normal and the ureter permeable, showed marked diminution of the urea output on the side of operation. In most cases ureterocystoneostomy, like circular suture and all the different types of reimplantation or anastomosis of the ureter, brings about, in a variable period of time (rarely exceeding two or three years), functional destruction of the kidney. If the destruction occurs gradually the condition is not serious, but in most cases there is a rapid onset of an intermittent hydronephrosis or renal infection, sometimes leading to urgent nephrectomy. Bégouin concludes, in accord with a number of leading surgeons, that this operation should be abandoned and if necessary replaced by the old ureteral ligation followed by nephrectomy. He suggests making this ligation high up above the operative field, after the presence of the other kidney has been determined by palpation and the peristaltic waves of the intact ureter have been seen. Nephrectomy is not necessary in all cases. If it is indicated, it may safely be performed from eight to fifteen days after the preceding operation.

[ED. NOTE.—This is a definite and interesting review of a series of cases which partially settles a much debated question, the disposition of the destroyed or severed ureter. While the number of cases cited is small, they show in a fairly conclusive way that if the opposite kidney is intact, conservative surgical measures are not usually indicated.]

*Ureteral Ligation.*—Helmholz and Field<sup>27</sup> report the results of an extensive experimental study of the effects of ligation of the ureter in rabbits. They have paid special attention to early and acute changes. Opinions from the literature are quoted. The changes that they find in the pelvis are: (1) hemorrhage, edema and exudation of leukocytes, which begin after four hours and reach a maximum in from eighteen to twenty-four hours; (2) destruction of small or large areas of the epithelial lining of the pelvis leading to ulcers or deep sterile abscesses in the peripelvic tissues; (3) healing beginning after forty-eight hours by the proliferation of connective tissue cells and the removal of the destroyed leukocytes by polyblasts; (4) healing of the small lesions of the pelvis by the formation of a pyogenic membrane and the lateral

27. Helmholz, H. F., and Field, R. S.: Acute Changes in the Rabbit's Kidney, Particularly the Pelvis, Produced by Ligating the Ureter, *J. Urol.* 15:409-429 (May) 1926.

simple in operation. While not intended to supplant the use of urologic tables for operative and cystoscopic work such as those devised by Young and others, this apparatus will suffice for those who are not so fortunate as to have access to one of these more elaborate tables.

From the illustrations and sketches appended, the apparatus seems to be simple and adequate, and should fill a need in the equipment of small hospitals.

Dax<sup>38</sup> has observed three cases of obstruction with stricture of the urethra in 150 cases of prostatectomy. In the first case, the obstruction was complete and situated at the deep orifice of the canal at the level of its union with the prostatic pouch; this occurred a week after operation. Dax had taken care not to pull on the adenoma for fear of tearing a portion of the urethral mucosa. He believes that this urethral obstruction was due to the formation of an irregular and exuberant scar. Obstruction in the second case occurred nine months after prostatectomy at the orifice of the bladder, and was due either to a missed piece of adenoma in the prostatic pouch or to the persistence of a diaphragm composed of the prostatovesical mucosa. The first possibility may usually be avoided by careful digital examination of the prostatic pouch after operation; the other results from faulty technic. Obstruction in the third case occurred two months after operation, the result of stricture 3 mm. from the meatus from ulceration caused by the permanent catheter which had been badly tolerated and had caused continuous suppuration. To avoid the last complication, Dax advises the use of sounds of small caliber (15, 16 or 17), and if after antiseptic irrigations the catheter is not tolerated, it is better to remove it and let the hypogastric wound close by itself. The treatment should consist in dilatation, the obstacle eventually being destroyed with the dilator, and catheterization. Rarely, the bladder may have to be reopened.

Andre<sup>39</sup> says that stricture of the urethra following prostatectomy is not infrequent, but that "decentration" or misalignment of the urethrovesical juncture is rare. In 300 cases in which he performed prostatectomy, ten cases of stricture and two of "decentration" were found. The cause of strictures is not always known; in five of Andre's cases there had been no difficulty in enucleating the prostate. The stricture occurred from eleven days to nine months after operation. In four cases of stricture, the plane of cleavage had not been clear, and probably a lesion of the mucosa of the membranous urethra resulted. In another case, in which total prostatectomy was necessary on account of the

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38. Dax, L.: Obstructions et retrecissements de l'urethre apres la prostatectomie transvesicale, *Arch. franco-belges de chir.* 29:101-105 (Feb.) 1926.

39. Andre, M.: Retrecissements et decentrements de l'uretre apres la prostatectomie, *J. d'urol. med. et chir.* 21:374-377, 1926.

twelve; nephrectomy, thirty-three; nephro-ureterectomy, forty-eight; resection of one half of horseshoe kidney, one; exploration, stone not found (found in bladder later in five cases), thirteen; pelviolithotomy and ureterolithotomy, six; nephrolithotomy and ureterolithotomy, two; ureterectomy, partial (kidney removed previously), three; transperitoneal ureterolithotomy, one; removal through vagina, one, and transvesical ureterolithotomy, six.

The incision for ureterolithotomy varies with the site of the stone. If it is the upper third of the ureter, or if there is also an associated stone in the renal pelvis, a posterolateral incision is made. It is not necessary to extend the incision as far posteriorly as is usual in operations on the kidney. The upper third of the ureter and the ureterovesical angle may be exposed readily without delivering the kidney. In some cases the stone may be brought up into the pelvis and removed through a pelvic incision; this is especially desirable if stone is also present in the kidney.

If the stone is in the iliac or the pelvic portion of the ureter, a straight rectus incision gives the best exposure. The exact location of the incision depends on the site of the stone. If the stone is in the lower segment, the incision through the rectus muscle should be made directly down to the pubic bone and should be of ample length. The peritoneum is pushed toward the median line until the iliac vessels are uncovered. If not fixed by inflammatory or postoperative adhesions to the surrounding tissues, the ureter generally follows the retracted peritoneum and is found on its posterior surface. In cases in which the ureter is dilated, it may be readily located. In other cases, the palpation of the stone may determine the position of the ureter.

The position of the majority of stones in the lower portion of the ureter makes their manipulative removal possible in many cases. The two essentials to success in the cystoscopic removal of stones are adequate dilatation of the ureter and the shifting of the axis of the stone.

The first can be accomplished by the use of a dilator or by passing increasingly larger catheters or sounds up the ureter past the stone or by passing up several catheters at the same time. The authors prefer the latter method, since the stone on several occasions has lodged between the multiple catheters and been removed with their withdrawal. Usually such catheters are left in place for forty-eight hours; then each one is twisted separately and all are withdrawn together. Some stones will pass with the next voiding; most will be recovered within the first two days, and a few will pass after a week. When the stone becomes impacted in the wall of the bladder, its removal will be hastened by slitting the ureterovesical orifice.

Eighteen of the 240 stones removed by manipulative methods were in the middle third of the ureter, 118 in the lower third, sixty-three at the ureterovesical juncture, and twenty-four were intramural. Sixty-

making an aggregate of positive observations in approximately 25 per cent of the series. The femur of sixteen and the ribs of ten were affected, but always in conjunction with involvement of the pelvis. Of 246 cases in which roentgenograms were made of the lungs, they were diseased in twelve. In all of these, metastatic tumors were present in the spine or pelvis.

Of 178 cases in which prostatectomy was performed, there are completed records in 164 (92.1 per cent). In forty-seven a perineal operation was performed, and in 117 a suprapubic. The length of life following operation averaged thirty months for the group, nearly three times as long as when no treatment was given. Thirty-five of these patients are still alive, but half have not lived three years; of the seventeen others, twelve have lived more than five years and may be considered cured.

The clinical records of 112 cases treated with radium are reported. The dosage given averaged a little in excess of 2,000 milligram hours, and the patients lived an average of twenty-two months following their treatment. Of these, twenty-five are still living, nine more than three years, and four of these nine have lived more than five years. These results are about equal to those obtained by surgical treatment, considering that these cases were not as carefully selected. Just as the surgical results did not warrant the continuation of that form of treatment except in selected cases, so the results of radium treatment compelled its abandonment.

If, as is usually the case, there is only a small amount of residual urine present, its removal by the daily use of the catheter will probably be sufficient to maintain adequate renal function. If the obstruction is more complete and a catheter passes with difficulty, cystostomy is indicated. This was performed in 125 cases in the series, of which there are complete records of 117. The average duration of the disease was nearly twice as long, being fifty-seven months instead of the usual thirty months for patients who received no treatment. After operation these patients lived an average of twenty-four months, more than twice as long as the patients for whom cystostomy was not performed. Thirty-four are still alive, eleven more than three years after operation, and of this eleven six have lived more than five years.

Marion<sup>42</sup> divides prostatic cancer into two anatomic groups: the cancer "proprement dit" or glandular carcinoma, and the cancer resulting from the transformation of periurethral adenoma. The diagnosis is not difficult; it may be confused in rare cases with an unusual lesion: diffuse ligneous prostatitis. In the early stage the carcinoma may be

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<sup>42</sup>. Marion, G.: A propos du traitement du cancer de la prostate, *J. d'urol. mèd. et chir.* 21:386-396, 1926.

downward extent of the tumor, with special reference to the possibility of multiple growths.

Radical operation is indicated in treatment. In most instances nephro-ureterectomy, either complete or partial, is the method of choice. Fulguration of tumors situated at the lower end of the ureter has given encouraging results in cases unsuited for the more radical surgical measures.

#### BLADDER

*Diverticula.*—Lurz<sup>31</sup> differentiates true diverticulum of the bladder and trabeculation. The true diverticulum contains muscle fibers and connective tissue representing the vesical wall as well as the lining of epithelium. False diverticula, such as those produced by rupture of abscesses into the wall or pericystic phlegmons, are considered as a separate group.

The microscopic picture of the true diverticulum shows that it never corresponds entirely to the normal vesical wall. The epithelial layer is thinner, lacking in the usual layering, and the wall consists for the most part of connective tissue with lymphocytic infiltration and a few muscle fibers. In form diverticula may be cone-shaped, oval, pear-shaped, angular (if attached to contiguous organs), round, or saccular. In number they may vary from one to forty.

Lurz has compiled from the literature 1,407 cases of so-called congenital diverticulum. To these he adds nine cases from Enderlen's clinic at Heidelberg. Only thirty-nine cases occurred in women. Three were found in fetuses. The majority occurred in men more than 50 years of age.

From the standpoint of etiology Lurz believes that true congenital diverticula do not occur. The various theories based on anatomic and embryologic studies to show that diverticula develop from anomalies in the embryo are reviewed. Kaufmann believes that the region of the lateral wall of the bladder in front of the ureteral orifices, the base of the bladder beyond the interureteric ligament, and the vertex of the bladder corresponding to the vesical end of the urachus are predisposing points for the development of diverticula. Thus, anomalous developments of the rests of ureteral buds, of the urachal ending in the bladder, and the like, might give rise to diverticula. It has not been demonstrated that intra-uterine obstruction of the urinary tract is a causative factor. If this were true there would be, according to Lurz, concomitant hydro-ureter and hydronephrosis. He states that there is probably some developmental weakness in certain portions of the vesical wall but that the diverticulum itself develops as a pulsion sack. The

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31. Lurz, L.: Ueber sogenannte kongenitale Blasendivertikel, Ztschr. f. urol. Chir. 18:278-299, 1925.



gubernaculum, just below the testis, is transfixed and ligated; the ends of the ligature are left long and are secured by a pair of Spencer Wells forceps; the redundant portion of gubernaculum beyond the ligature is cut away. An incision is made on the opposite side of the scrotum, and a bed for the testis to be transplanted is made between the septum and the normally placed testis. The forceps with the ends of the ligature are introduced through the incision in the external oblique muscle and are directed along the inguinal canal, through the external ring, and well down into the scrotum; they are then made to impinge against the septum, which is pushed before them into the scrotal wound. A small incision is made in the septum over the points of the forceps, which are then pushed through, and the ends of the ligature are secured. The forceps are withdrawn slowly and are opened from time to time so as to make a way for the passage of the testis, which is drawn into its new position by traction on the ligatures.

Turner sets himself high standards and follows his cases thoroughly. In 70 per cent of his cases, the results were splendid. In 16 per cent they were poor, but by no means failures, and in 14 per cent atrophy and failure are recorded.

*Cancer.*—Handfield-Jones<sup>44</sup> reviews the work on chorionic carcinoma from the time of Sanger's first description of a chorionic epithelioma to the present time. Handfield-Jones states that certain definite histologic characteristics must be present to make a pathologic diagnosis. These elements are the syncytium, Langhan's cells, chorionic wandering cells and the masses of blood and fibrin. Chorionic carcinoma is highly malignant, producing widespread metastasis through the blood stream. The lungs are the usual site of deposit, the secondary deposits usually resembling the original growth. Dissemination may also occur by way of the lymphatics to the aorta and inferior vena cava. It is of interest to know that occasionally in the uterine cases there is spontaneous repression of the metastatic lesions with the removal of the primary growth. Attention has been drawn to the fact that in some cases there has been activity in the male breast in that it may enlarge and secrete colostrum. There are numerous theories regarding the site of origin; the generally accepted view is that it arises from some element in a teratoma and that the formation of true fetal membranes is not necessary.

[Ed. NOTE.—Clinically these testicular tumors do not differ from other testicular malignant neoplasms. The general symptoms vary with the site of the metastatic tumors. By far the most common symptoms

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44. Handfield-Jones, R. M.: Chorionic Carcinoma in the Testicle: With a Report of a New Case, *Brit. J. Surg.* 13:606-620 (April) 1926.

Division of the diverticular neck intravesically is practiced by some when the diverticulum is situated close to the internal sphincter or goes deeply toward the rectum.

Lurz emphasizes the importance of abating prostatic hypertrophy or other urinary obstruction either at the same operation or before or after the excision of the diverticulum. Different authors recommend a different order of operative procedures under these circumstances, but to remove the obstruction and not the diverticulum, or vice versa, leaves the result unsatisfactory.

[ED. NOTE.—This is an excellent review, and the opinions of most of the leading urologists on the subject are brought together. Certainly conservative treatment can lead only to a poor result, while the operative mortality is not excessive and the end-results of surgical treatment are on the whole good. Many points in the treatment of vesical diverticula are open to argument, especially as to technic of approach, type of excision, the treatment of tumors and prostatic hypertrophy at the same or a subsequent time. More studies of the type that Lurz has presented will aid in the solution of these problems and may help to lower the operative mortality, in the same manner as that of the enlarged prostate has been lowered.]

*Nerve Control.*—Grouvall<sup>32</sup> reports his experimental work on the nerve control and mechanism of micturition. His experimental procedures were divided into the following stages: (1) The bladder was filled with urine; (2) the intravesical pressure was raised until equal to that of a column of water 12 cm. high; (3) rhythmic contractions of the bladder were then observed; (4) an afferent impulse was then given to the bladder through the nerves erigentes and hypogastrici, which caused a contraction of the detrusor muscle and an increase in the intravesical pressure up to 30 cc. of water; (5) the sphincter vesicae was dilated reflexly and the urine passed into the urethra; (6) the bladder emptied itself, and (7) the last few drops of urine were expelled through rhythmic contractions of the smooth and striated muscles surrounding the urethra.

#### PROSTATE

*Electrocoagulation.*—Walker,<sup>33</sup> realizing the value of punch operations in selected cases of prostatic obstruction, and preferring diathermy to galvanocautery, as used in Caulk's instrument, devised a new instrument. In external form it resembles the Young punch, but the sheath is constructed of bakelite, an excellent insulating material allied to

32. Grouvall, H.: Mechanismus der Blasenentleerung. Ztschr. f. urol. Chir. 19:173-174, 1926.

33. Walker, K. M.: A New Diathermy Punch for Prostatic Obstruction, Proc. Roy. Soc. Med. (Sect. Urol.) 18:35-38 (Aug.) 1925.

Rubaschow found only thirty-eight scrotal tumors in fifty years. The majority were embryonic in origin; even the lymphangiomas may have their origin in embryonic anlagen which belong to the retroperitoneal tissues. In frequency of occurrence of tumors, the organs most frequently involved are the testis, cord, tunica vaginalis and scrotum, respectively.

#### ANESTHESIA

Arce <sup>46</sup> reports on the type of anesthesia used in the University Surgical Clinic in Buenos Aires. Lumbar anesthesia reduces the blood pressure and causes the patient to faint or collapse. To employ this type of anesthesia without danger to the patient in operations of the lower limbs, the perineum, the genito-urinary organs and the abdomen, the blood pressure must be within normal limits.

In operations on the scrotum, testes, penis and spermatic cord, Arce injects from 0.08 to 0.1 Gm. in the second lumbar space. In operations on the kidney and upper part of the abdomen, he injects 0.1 Gm. in the eleventh or twelfth dorsal space.

#### CHYLURIA

Kutzmann <sup>47</sup> reports a case of nonparasitic chyluria of three years' duration in a male negro, aged 21. The patient was later shown to have a perirenal abscess about the upper pole of the left kidney. The chyle came from this kidney, and the chyluria disappeared after nephrectomy.

In a review of the literature, an excellent discussion of the theories on nonparasitic or nontropical chyluria was found. This was advanced to explain this much misunderstood condition. The theories center around the supposition that the kidney through some abnormality of metabolism secretes or excretes the chyle which is abnormally present in the blood, and around a second and more feasible theory that there is some abnormal connection between the urinary tract and the larger lymph channels. Several instances of such abnormal communication having been demonstrated are cited. The route between the intestinal and the renal lymphatics is not well understood. According to Magnus-Levy, the chyle must first go through the mesenteric lymph channels to the mesenteric lymph nodes and thence to the thoracic duct. Thence, because of obstruction, there is a retrograde flow to the upper lumbar nodes, which drain the renal lymphatics. To obtain such a retrograde

<sup>46</sup>. Arce, José: Die Lumbalanästhesie in der Chirurgie, *Deutsch. med. Wchnschr.* 1:644-646 (April 9) 1926.

<sup>47</sup>. Kutzmann, A. A.: Nonparasitic Chyluria, *Ann. Surg.* 82:765-780 (Nov.) 1925.

which prostatectomy is contraindicated, and occasionally in cases of postoperative obstruction and malignant disease.

Hammond<sup>34</sup> reviews briefly the various operative and nonoperative procedures used for the relief of prostatic obstruction. He finds that in selected cases the most gratifying results are obtained by the application of surgical diathermy through an operating cysto-urethroscope. The adenomatous enlargements should be carefully separated from the fibrous ones. With the fibrous and atrophied prostates the urethra is not compressed throughout its length, and the obstruction is at the neck of the bladder. When the bladder is opened in these cases, it will be found that there is a narrowing of the internal meatus, but that, when the finger is passed through this, the prostatic urethra appears more dilated than usual. This type of prostate does not tend to become progressively larger, and the obstruction is localized in the vesical neck; the latter can be easily destroyed and removed, and does not tend to recur. After treatment by diathermy, shock and hemorrhage are never severe enough to cause any worry; the convalescence is much shorter than after prostatectomy, the functional result is better, and the mortality rate is lower. When it is remembered that the type of prostate which is treated by diathermy is that which is largely responsible for the mortality after prostatectomy, it is obvious that a careful selection of cases will lead to an improvement in the statistics of this operation. If there is renal failure or marked infection, Hammond institutes preliminary suprapubic drainage.

*Prostatectomy.*—Hunt<sup>35</sup> advocates the use of Pilcher's modification of the Hagner bag as being superior to other methods of control of bleeding following suprapubic prostatectomy. Hemostasis in prostatic surgery has not formerly been given the consideration that it has been given in other fields of surgery. It is to be expected that there will be some hemorrhage, which often becomes a serious factor. The various methods of packing the prostatic capsule with tampons, pressure sticks, kephalin gauze and the like are reviewed. Following the removal of such packs granulations are often broken and severe secondary hemorrhage is induced.

Hunt describes his technic of one-stage suprapubic prostatectomy under vision. He supports himself with statistical evidence in the statement that 75 per cent of cases can be safely brought to this one-stage procedure with proper preliminary preparation. He emphasizes the fact that the Mayo Clinic figures formerly showed that the mortality rate was

34. Hammond, T. E.: Diathermy in the Treatment of Prostatic Obstruction, *Brit. M. J.* 1:94-95 (Jan. 16) 1926.

35. Hunt, V. C.: Hemostasis in Suprapubic Prostatectomy, *Ann. Surg.* 83:381-391 (March) 1926.

investigation. The addition of ether will clear the specimen, and the fat thus may be obtained by extraction. The entire urinary tract should be thoroughly examined and a good general examination carried out to expose possible related pathologic changes. It would seem that conservative treatment with diet, lavage and the like should always be the first therapeutic effort. Operative treatment for such a condition alone seems radical and hardly indicated in uncomplicated cases.]

Any procedure that is systematized and carefully worked out and controlled gives better results than varying methods occasionally employed.]

Dodson<sup>36</sup> calls attention to the fact that hemorrhage and shock are second and third in importance as causes of death following prostatectomy. The blood vessels of many old men suffering from prostatic hypertrophy are so sclerotic that they do not compensate well for the loss of fluid from the vascular system. The relief following intravenous injections of sodium chloride solution and of glucose, while important, often is only transitory. Dodson recommends that transfusions of whole blood be carried out more frequently, since they supply the elements necessary to combat the loss of blood cells. Whole blood replaces the lost fluid, improves the quality of the blood and, by decreasing the coagulation time, is a valuable asset in the control of bleeding. Transfusions of whole blood are preferred to citrate transfusions because of the relative infrequency of reactions from the former technic.

Seven cases of prostatectomy in which blood transfusions were employed are reviewed. Four of these were cases of carcinomatous prostate, and in all there was some degree of arteriosclerosis. In two cases transfusion was given because of hemorrhage, in two because of shock, and in three because of gradual failure of the circulation and inability to "rebound." Two of the patients in the last group died. In both there was extensive carcinoma of the prostate, and the risk was extremely grave.

While it is not asserted that transfusion is a panacea, it is held that it is a procedure of merit which should be more frequently employed postoperatively in this class of case, and that as a part of the preliminary procedure the blood should always be matched for blood transfusion.

[ED. NOTE.—We believe that the advocacy of transfusion for the patient who is not doing well after prostatectomy is founded on good therapeutic principles. Especially is this true in cases of hemorrhage and shock. The administration of large quantities of sodium chloride solution is by no means to be dispensed with. Transfusion is added as a further supportive measure, and it would seem should often turn the tide toward a satisfactory convalescence.]

Bidgood<sup>37</sup> describes in detail an attachment which can be placed on any ordinary operating table in such a manner that the perineum of the patient can be elevated to the proper level for surgical approach to the prostate or seminal vesicles. The ideal position of the patient for this work is such that the perineum is parallel to the floor. The apparatus is made of steel and aluminum, and its various parts are

36. Dodson, A. I.: The Value of Blood Transfusion in Surgery of the Prostate, *Ann. Surg.* 82:974-977 (Dec.) 1925.

37. Bidgood, C. Y.: A Perineal Elevator, *Ann. Surg.* 83:126-130 (Jan.) 1926.

That portion of the products of digestion which pass into the portal circulation primarily pass through the liver. In the liver, part of the material is changed in, or by the agency of, the liver cell, and the products of this change pass out in the biliary tract in the bile while the remainder passes into the systemic circulation.

The liver represents a powerful agency for discrimination between the preceding part of the picture (that is, the portal area) which represents the height of production and the succeeding part of the picture which represents elimination. In the liver, a separation occurs between those bodies obtainable from the food intake which are useful to the body economy and the residue of by-products which are useless and which may become harmful. Elimination of these by-products, harmful or otherwise, occurs (1) through the biliary tract and out through the lower intestine, and (2) through the systemic circulation after detoxification through the urinary system.

Up to this point in the cycle, the blood contains eliminatory bodies which are derived solely from the breaking down of the food materials.

The systemic circulation represents the peak of production and distribution. The products of digestion are distributed throughout the body, and are utilized in the structural units of the tissues. In the process of utilization, catabolistic bodies appear which are destined for elimination from the body.

At this stage of the metabolic activity of the body, the systemic circulation contains two distinct sets of excretory bodies; the previously mentioned group, which is derived from and during the digestion of food, and a group resulting from the breaking down of the structural units of the tissues. As the materials for the structure of the food and of the tissue units are essentially the same—proteins, fats, carbohydrates, etc.—it is found that within certain restrictions each set of excretory bodies has a generally similar chemical structure. Both of these distinct groups mingle in the systemic circulation. From this point, elimination increases and becomes dominant.

A third set of excretory bodies is derived from the breaking down of the coloring matter of the blood. These bodies ultimately become the bile pigments and are excreted from the body economy into the bile.

The organs of elimination include the kidney, the intestinal tract, the skin and the pulmonary surface. The intestinal tract differs from the others in that some of the bodies excreted into its lumen for purposes of elimination are reabsorbed into the system to be handled and reexcreted again through the biliary tract into the intestine or to be passed out of the body through the kidney. Each of these avenues of elimination can under given circumstances attempt to assume the excretory functions of the others; the degree of compensation is, however,

impossibility of enucleating the organ, a tight stricture developed. In most of Andre's cases, the stricture was cured by dilatations; in two of them internal urethrotomy was required: In the two cases of "decentrement" the fact that micturition had been easy, without effort and of normal frequency, whereas catheterization had been impossible, led to the diagnosis. These complications can be avoided if care is taken not to tear the urethral mucosa in removing the adenoma. The vesical mucosa should be severed at the bases of the prostatic lobes and not at the top. When a well developed median lobe is present, the mucosa should be removed completely from before backward, so as not to leave floating fragments which might later act as a valve during micturition. In some cases it is advisable to dilate the urethra at monthly intervals following operation.

Rubritius and Schwarz<sup>40</sup> state that contracture of the vesical neck is not an entity, and that the most varied anatomic changes of the sphincter and the nerve supply lead to retention. If the whole group is brought under one name, that name will convey only the meaning of a symptom, namely, retention. The common functional factor in practically all cases of retention is hypertonus of the sphincter, which is the same whether brought about by a small adenoma or by inflammatory contractions. In one group of cases the hypertonia stands out so markedly that it must be considered as the entire cause of the retention. The outstanding method of treatment consists in a transvesical incision into the sphincter with enucleation of any periurethral adenomas that may be present.

*Cancer.*—Bumpus<sup>41</sup> reports 1,000 cases of carcinoma of the prostate seen at the Mayo Clinic prior to January, 1925. The average age of the patients was 65 years; in no case was it encountered before the forty-second year, and rarely before the forty-fifth year. In 485 cases in which no treatment was given, the average duration of the disease from the first symptoms to death was thirty-one months. When metastasis had occurred at the time of examination, two thirds of the patients died within nine months. When careful examination indicated that metastasis had not occurred, the average subsequent length of life was approximately one year. In 136 cases the urine was negative, and in 137 cases gross hematuria was noted; in 362 cases erythrocytes were found on microscopic examination. In 243 of 1,000 cases, metastasis was demonstrable. In 44 per cent it had affected the lymphatics. Five hundred and thirty-nine patients were examined roentgenographically, and the pelvis of 123 and the spines of 107 were found to be affected,

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40. Rubritius, H., and Schwarz, O.: Contribution to the Problem of Contracture of the Neck of the Bladder. *J. Urol.* 15:461-465 (May) 1926.

41. Bumpus, H. C., Jr.: Carcinoma of the Prostate. *Surg. Gynec. Obst.* 43:150-155 (Aug.) 1926.



amino-acids are further decomposed by the action of the bacteria losing ammonia and being converted into fatty acids, or by decarboxylation being made into amines, some of which have a powerful action on the blood pressure and other functions of the body. Other ill-smelling and harmful substances are produced, such as some of the mercaptans, sulphurated hydrogen, indol and scatol.

#### NITROGEN METABOLISM

*Urea Formation.*—In the process of digestion and absorption of protein food, large amounts of ammonia are set free. This ammonia is liberated in part as the result of the action of the enzymes of the digestive juices; in part, by the action of the bacteria in the intestine, and in part, during the process of absorption, from the amino-acids of the proteins of the food. The ammonia thus liberated accumulates in the mucous membrane of the stomach and intestine, whence it is gradually removed by the blood and carried to the liver in the portal blood. The liver converts at least part of it into urea, and the kidney eliminates it from the body. Another portion of ammonia is set free in the liver itself from the decomposition of the amino-acids brought to that organ in the portal blood, and the carbon moieties of those molecules are converted in part into glucose and glycogen. A relatively large fraction of the nitrogen of the food thus never becomes part of the living protein of the body, but is converted into urea and thrown out of the body. On a meat diet the amount of nitrogen thus converted into urea, so-called superfluous nitrogen, is relatively large. It is not certain just how large it is, but it probably is at least a third of all the nitrogen in the urine, since on fasting the urea drops at once to about two thirds its former value. Certainly with an output of 35 Gm. of urea a day, this digestive nitrogen will represent at least 10 Gm. of urea. This is not the only origin of the urea. The tissues are also capable of tearing their protein to pieces and deamidizing the amino-acids. For example, if a muscle has not a sufficient amount of carbohydrate to supply its energy, it will tear its protein to pieces to get the energy. This is always accompanied by a process of oxidation, during which process a ketonic acid is formed from the amino-acid and ammonia is set free. Lactic acid is formed in muscles during their work; some ammonia probably escapes from the muscles in the form of ammonium lactate, and this is in part made into urea. The endogenous urea has, therefore, a varied origin, coming from the different organs in the form of a variety of nitrogenous substances which are somewhere, most probably in the liver, made in part into urea. Even on the minimum protein diet of only 3 or 4 Gm. of nitrogen intake a day, the urea still makes 60 per cent or more of the total nitrogen in the urine.

mistaken for simple hypertrophy, but if the seminal vesicles are enlarged carcinoma should be considered. Hard nodules usually mean malignancy; irregular masses are rarely inflammatory in origin. The treatment varies following the operability or nonoperability of the tumor. The operability is defined by the absence of diffusion in the periprostatic and perivesicular tissues and of unexplained persistent pains. The so-called cancer originating in the gland itself is rare on account of the fact that patients usually seek relief only if there is pain, a late symptom in this type of cancer. The opposite is true for carcinoma originating in periurethral adenoma, which causes early dysuria and frequency. Both types of tumor should always be extirpated when possible. Definite cures are not frequent (three in forty-eight of Marion's private cases), but many patients (twenty-six out of forty-eight) keep regular function of the bladder up to the end. The operative mortality in Marion's cases was 10 per cent. All but 6 per cent of the patients that lived after operation derived some benefit from it. Marion uses the suprapubic route in removing malignant tumors of the prostate, believing that it is not more serious than the perineal operation and that it gives the patient immediate relief without the risk of fistula, other sequelae, or a long convalescence. The seminal vesicles should be removed with the prostate, and the catheter should not be inserted until from fifteen to twenty days after operation. Marion does not favor radium; he believes that even in inoperable cases the results are unsatisfactory. Cystostomy is indicated only when catheterization is difficult or has to be repeated frequently, or when it causes hemorrhage.

#### TESTIS

*Orchidopexy.*—Turner<sup>43</sup> describes the results of his operation for undescended testis. The operation is briefly as follows: A small incision is made in the external oblique muscle just above the internal abdominal ring. The internal oblique muscle is drawn upward, and the spermatic cord, enclosed with the patent funicular process in a sheath derived from the infundibuliform fascia, is exposed just below the internal ring. The spermatic cord and the testis are drawn out from the inguinal canal into the wound; the hernial sac, or the patent processus vaginalis, which is nearly always present, is separated from the vas and the veins after the fascial sheath has been opened, and is ligated above at the internal ring and below just above the tunica vaginalis. The facial sheath of the cord is divided, and the attachment of the gubernaculum to the tissues of the groin is torn through. The

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43. Turner, Philip: An Analysis of the Results in Fifty Cases of Transseptal Orchidopexy for Imperfectly Descended Testicle, *Guy's Hosp. Rep.* 75:209-221 (April) 1925.

quantitatively recovered in the urine. Uric acid injected into animals with the liver and both kidneys removed is slowly absorbed by the muscles, so that it does not all remain in the circulating blood. Determination of the uric acid content of the blood and muscles several hours after injection shows that the total amount is retained in the body and that little of it could have been destroyed. The uric acid accumulated in the body of hepatectomized neprotomized dogs is of the same magnitude as that excreted by the kidneys of hepatectomized animals. The uric acid excreted by the hepatectomized animal is of the same magnitude as the allantoin excreted by the normal dog. The destruction of uric acid in the normal dog depends on the presence of the liver, as this process ceases as soon as the liver is removed.

*Creatinine.*—There is excreted in the urine of adults about 1 to 2 Gm. of creatinine a day. The amount is entirely independent of the protein intake, but is increased by the ingestion of creatinine, most of which reappears unchanged in the urine. The ingestion of creatine increases creatinine slightly, if at all; it may increase somewhat the creatine excretion. What becomes of the greater part of the creatine thus ingested is unknown. Creatine is found only occasionally in small quantities in the urine of men, a few milligrams a day, but it occurs, or is supposed to occur, in larger amounts, from 60 to 100 mg. a day in the urine of women during menstruation, in the first few days after childbirth and during pregnancy. It is usually present in children's urine, particularly in girls', and may comprise from one tenth to one third the amount of creatinine.

The amount of creatinine excreted in adults is roughly proportional to the body weight, from about 7 to 11 mg. of creatinine nitrogen per kilogram body weight being excreted in twenty-four hours. This figure is called the creatinine coefficient. The combined creatine and creatinine content undergoes little change during fasting, but the amount of creatinine diminishes and that of creatine increases, if the method of determination of creatine is correct. The same result occurs in carbohydrate starvation, in diabetes, both natural and phloridzin, and in the early stages of wasting diseases, such as fevers, muscle atrophy and other conditions. These facts show that creatinine has an endogenous origin, and that unlike urea it is unaffected by the intake of protein.

There is found in the voluntary muscles about from 0.35 to 48 per cent of creatine; large amounts are found also in the liver, the involuntary and heart muscle, in the brain, the testes and other organs. The total amount of creatine in the body is thus about 120 Gm. This creatine of the body is probably the origin of the creatine and creatinine of the urine. The muscles have the power of forming creatine from glycoamine, and they and other organs can turn creatine to creatinine. Extracts of the organs have this same power, which is probably to be

of secondary localization are pulmonary: dyspnea and hemoptysis. The chorio-epitheliomatous portions of the tumors are hemorrhagic and necrotic; microscopic examination reveals Langhans' cells with islands of syncytium intervening; there usually are numerous irregular blood spaces lined with flattened syncytial plates distributed between the Langhans cells. Besides the usual alveolar arrangement, the Langhans cells are found in a more independent proliferation consisting of duct-like and complex papillary forms lining cystic spaces. Besides the chorio-epitheliomatous portions, teratomatous elements are found in about half of the cases.

The pathogenesis of these testicular growths is a disputed question, as is that of the other testicular malignant neoplasms. Chorio-epithelioma is trophoblastic and yet the presence of teratomatous elements must also be explained. Three possible points of origin have been suggested: (1) from interstitial cells of the testis, (2) from misplaced multipotential cells included during embryonic development, and (3) from the spermatogenic cells. The fact that no case occurring before puberty or after cessation of sexual activity has been seen, is used as an argument against the possible association with spermatogenesis. Ewing has suggested that it is hazardous to attempt the diagnosis of chorio-epithelioma of the testis in the absence of pulmonary or hepatic metastasis.]

#### SCROTUM

*Tumors.*—Rubaschow<sup>45</sup> states that tumors of the scrotum (skin growths excluded) are rare. They have the same characteristics as other tumors of the genital system; they are highly malignant and are, etiologically, difficult to classify. Rubaschow has divided these tumors into two main groups, the teratomatous or heterotopic tumors and tumors of the local tissues. Metastatic growths are not considered.

Under heterotopic tumors are included: (1) teratomas and dermoids, probably related to teratoma testis, and (2) mesodermal growths, thought to originate from the embryonic myotome and sclerotome, or possibly body rests carried down with the descent of the testis. The mesodermal tumors include myomas, fibromyomas, chondromas and osteomas, and are divided into four types: (1) fibromas with some smooth muscle; (2) chiefly myomatous tumors also containing some fibrous tissue, resembling the fibromyoma; (3) those with only muscle tissue, leiomyomas, and (4) those of embryonic striped muscle, rhabdomyomas. Genetically they are either teratomas with an excess of muscle tissue or they are of true mesodermal origin. Lipoma, sarcoma, angioma or lymphangioma may arise from other scrotal tissues.

<sup>45</sup> Rubaschow, S.: Die Geschwülste des Hodensacks (Hautgeschwülste ausgeschlossen), Ztschr. f. urol. Chir. 19:218-230, 1926.

## BLOOD NITROGEN

Knowledge of blood chemistry is of comparatively recent origin. The work of Folin and Denis in the development of a simplified technic for the accurate estimation of blood urea probably gave the first great impetus to this investigation. Determinations by modern methods are feasible for any well equipped clinical laboratory and the technic of the procedure can readily be mastered. The development of simplified methods of estimating the amount of the various substances in health and disease has rapidly led to the accumulation of much data concerning their variations.

*Blood Urea.*—The normal urea content of the blood is subject to considerable variation. It is recognized as varying normally from 20 to 40 mg. per hundred cubic centimeters. In the interpretation of the content of the blood in every given case, the diet of the patient must be taken into consideration. It is at once apparent that a blood urea content of 50 per cent in a person on a nonprotein diet has not the same significance as the same level of blood urea in a person whose protein intake is high. Another factor which should receive consideration in the interpretation of the blood urea level is the fluid intake. It has been noted repeatedly that a high blood urea content can be reduced noticeably in many instances following the ingestion of large amounts of water. The amount of urea excreted can be shown to vary considerably with the amount of urine output. This is especially true when the renal damage is not extreme.

Other things being equal, a rise of blood urea above normal is primarily to be interpreted as an index of bilateral renal insufficiency; however, it is common experience that not infrequently patients can maintain a fair degree of health for a considerable period of time with a urea of 80 mg., and in occasional cases at a point considerably higher. On the other hand, there is occasionally definite uremia with a blood urea content within the normal range, so that an accurate prognosis cannot always be drawn from the urea content alone, as it is frequently necessary to take other factors into consideration.

When the blood content of urea rises to 100 mg. or higher, the prognosis becomes increasingly grave. An amount above this level can seldom be maintained for any considerable period without grave symptoms of renal insufficiency. In acute renal processes, in acute exacerbations of chronic renal disease or in urinary obstruction, the urea level may rise to an astonishingly high figure without a necessarily fatal termination, with subsequent recovery and a return of the urea to the normal level. Numerous instances of this kind have been reported frequently. These high figures are rarely attained in cases of chronic renal insufficiency, and when they occur nearly always terminate fatally.

flow an insufficiency of the valvular system of the lymphatics must be assumed. Assuming a lymphatic block in the renal lymphatic system, leakage of chyle may occur through the kidney. According to the researches of Stahr and Kumita, the lymph channels of the renal cortex can be injected from the capillary bed of the muscularis of the small intestine. Goebel states that to have chyluria, first, the lymph channels must open into the urinary tract and, second, the lymph channels must empty their contents through recurrent channels into these lymph channels of the urinary tract. Marion assumes a secretory and an excretory type of chyluria. Nearly all hypotheses are insufficient and little better than those advanced many years ago.

Nonparasitic chyluria is rare in America; it is more common on the European continent. More than 100 cases have been reported. It occurs chiefly during early and middle adult life; only twelve cases have been reported in children. Milky or turbid urine usually is the only primary symptom. This may be complicated by backache or renal colic. It may be constant or intermittent, and it may occur at different times of the day.

The urine has been the subject of much study. Usually, it will contain from 1 to 3 per cent of fat by Babcock's method. Occasionally erythrocytes or leukocytes may be found, fibrin clots are frequently found, and the urine often has a pinkish tinge. The differentiation from lipuria, such as is found in phosphorus poisoning, and degenerative renal processes, and from pyuria must be carefully made. The history of residence in tropical countries should lead one to suspect the parasitic or filarial form. Chyluria associated with diabetes, pregnancy, the puerperium, tuberculosis of the peritoneum and carcinoma in the region of the kidney has been noted.

The disease is one of long duration, and because of its benignity has a fair prognosis. One case of fifty-five years' duration is cited. Treatment is entirely empirical. A low fat diet has given good results in a number of cases. Renal lavage with weak solutions of silver nitrate may be tried. Fulguration or cauterization of demonstrable points of communication has been successful at times. Exploration of the kidney and nephrectomy have been performed in poorly progressing cases. Some observers have abolished the symptoms with neoarsphenamine.

[ED. NOTE.—The obscurity that clouds the etiology of chyluria of any type makes its proper treatment difficult. More study of the relation of the renal lymphatic channels is necessary. Probably this condition frequently passes by undiagnosed in the course of routine clinical examinations. Murky urine which does not clear on heating or the addition of acid, and which contains no formed bodies, should lead to

*Blood Creatinine.*—Quantitative determinations of blood creatinine give information concerning one of the end-products of endogenous metabolism. The amount of creatinine in the blood is not influenced, as is urea, by the protein intake, so that it would be expected that a rise of creatinine above normal would be a truer index of tissue metabolism. The normal blood content of creatinine averages about 2 mg per 100 cc., and as a rule, there is no appreciable increase in this amount until well marked renal insufficiency is present, as determined by blood urea and phenolsulphonphthalein estimations.

When there is a marked increase of creatinine, 5 mg or more, a serious disturbance of renal function occurs. The combination of a high urea content of the blood with a high creatinine content of the blood offers a distinctly graver prognosis than the same amount of urea with a normal creatinine content. It is at once apparent that the value of this determination as a functional test is limited and is by no means as delicate an index of renal function as the estimation of blood urea; furthermore, it seldom gives information which is not obtained by the determination of urea. It has been found by Squier and Myers, and by Frontz and Geraghty, that creatinine is much more readily excreted than urea and uric acid, and that considerable diminution in renal function can occur before there is any rise in the creatinine level.

*Amino-Acids.*—The hope of gaining unusually valuable facts from the contemplation of the amino-acid content of the blood has also not been realized. Folin has pointed out that this is what one might be led to expect. Deamination must be a prelude to the destructive utilization of much of the protein material either ingested or liberated from tissue sources. The long debated theory that deamination precedes in the walls of the intestine has been abandoned. One might readily expect anomalies of deamination to occur as manifestations of metabolic disorder; indeed, the well known failure of cystine to be consumed in the organism of certain persons furnishes an illustration of this type of defect. But, with the exception of rare instances of such inborn errors of metabolism, deamination abnormalities appear to be of rare occurrence. Folin has remarked that the deamination process appears to be such a fundamental process that one cannot expect to find many pathologic conditions in which the amino-nitrogen of the blood filtrates will vary much from the normal.

The amino-acid content of the blood represents a food product on its way from the intestine to the tissues. The amount of amino-nitrogen in the blood varies between 4.8 and 7.8 mg. in 100 cc., the average amount being 6.3 mg. This was found by Greene, Sandiford and Ross to be true in normal persons, and in a series of more than 400 observations covering twenty pathologic conditions. A definite increase in the amino-nitrogen content of the blood during protein digestion was first

## RELATION OF NITROGEN BODIES OF BLOOD TO SURGICAL PROBLEMS IN LIVER AND IN BILIARY TRACT DISEASE

I. INTERRELATIONSHIPS OF NITROGEN BODY METABOLISM AND  
CRITERIA ON WHICH JUDGMENTS ARE TO BE BASED \*

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Retention of nitrogen bodies in the blood stream is the most important characteristic of a form of general intoxication of the body which is a common factor in a number of clinical conditions associated with disease of the liver, with disease of the intestinal tract and with disease of the urinary tract. Obstruction to the natural outflow of the normal excretions in each of these three sets of organs is frequently found, clinically, with this form of general intoxication. Evidently there is a common cause for the development of this intoxication, or a group of causes which, because of a common mechanism in the normal interrelated functions of these generally allied groups of organs, results in a common secondary lesion to which the retention of nitrogen bodies in the blood is due.

A cursory view of the facts available in this general class of disease brings the conviction that this is an extremely complicated problem or group of interrelated problems, and it is apparent that a satisfactory elucidation of the mechanism present and of the causes for this general form of intoxication can follow only after the normal mechanisms and processes are completely understood. This is the purpose of the preliminary article.

### ANATOMIC PATHS

The chart is a graphic representation of the general interrelationships of three allied groups of organs: the liver, the intestinal tract and the systemic circulation.

The first stage in the absorption of the products of digestion of nitrogenous foodstuffs from the alimentary canal takes place from the small intestine into the portal circulation and into the thoracic duct. The lymphatic flow in the latter path communicates directly with the systemic circulation.

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\* From the Mount Sinai Hospital.



conclusively demonstrated by Van Slyke, who utilized his own nitrous acid method. Subsequent investigations have shown the possibility of following the metabolism of these bodies, their storage in the liver and muscles and their ultimate deamination in the latter organ. Apart, however, from the great increase in the amino-nitrogen content of the blood in acute yellow atrophy—an increase which is in part attributable to the massive tissue autolysis which is occurring, and in part to the failure of deamination resulting from destruction of the liver tissue—the estimation of these bodies is at present of little importance in medical practice.

#### CLINICAL FACTS

Indications of all of the metabolic changes referred to in the previous part of this article, whether they be derived from ingestion or from tissue breakdown, are distinguishable in the actual and relative proportions of all of these important bodies as they are being transported in the blood stream. However, when an attempt is made to correlate the relative and proportional status of these bodies at any given moment with conditions of health and disease, it is found that constancy does not exist; seemingly, there is an extraordinary amount of confusion; and this seems especially to be the case in the correlation of the blood figures with pathologic states. The wide extent of the "normal" variation is another source of difficulty. The observations in various conditions are of great interest in this regard. These are shown in tables 2 to 5.

*Summary.*—The chemical composition of the peripheral blood depends on the chemical composition of the cellular elements of the blood and on the chemical composition of the blood serum. The first of these is a constant factor. The second of these, the blood serum, is a constantly varying combination of numerous constituents which can roughly be divided into a group of bodies that are on their way to being built into established tissue elements, that is, the amino-acids; a group of bodies which are derived from tissue catabolism and represent structural wear and tear; a group of bodies similar to those in the previous two groups, which are derived from the ingested food during digestion and represent the wastage of an excess food supply, and a series of bodies due to the action of intestinal bacteria on the digestion residues in the alimentary canal. At any given moment the relative proportions of all of these varying groups of bodies existing in the blood serum represents a balance between the withdrawals and additions from and to the blood stream.

Exaggerations of all of these variations accompany certain physiologic epochs (1) in the daily life of any person, that is, the taking of food, periods of exercise, periods of sleep; and (2) in the life cycle, that is, pregnancy. Extreme variation occurs between persons between successive periods of life, and with certain underlying manifestations which one is accustomed to designate as "diathesis."

of only relatively small degree, and in actual conditions of disease, insufficiency of the one is not compensated to the degree compatible with health by any or all of the others.

The accompanying diagram shows the interrelationships of the paths of absorption and elimination.

#### DIGESTIVE CHANGES

The chief changes which the foods undergo in the intestinal tract and by which they are made available to the body by be summarized briefly as

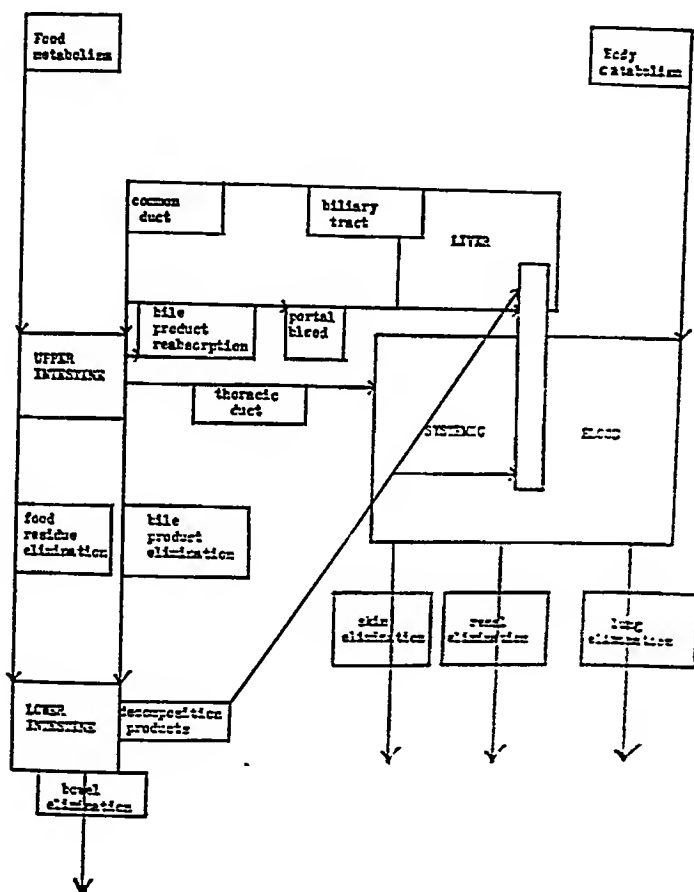


Fig. 1.—A graphic representation of the general relationships of the liver, the intestinal tract and the systemic circulation.

follows: The proteins by the action of pepsin hydrochloric acid of the gastric juice, by the intestinal and pancreatic juices containing entero-kinase, trypsin and erepsin, are resolved into the amino-acids, of which they are composed. The compound proteins, such as the nucleoproteins, are digested in part by the proteolytic enzymes and in part by the nucleases of the pancreatic juice, with the formation of phosphoric acid, nucleic bases, pyrimidin bases and presumably carbohydrate, from the nucleic acid. Hematin is split off from hemoglobin. Some of these

# TORSION OF THE GALLBLADDER \*

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Torsion of the gallbladder is a rare condition. I have been able to find only two American reports, that of Wendel in the *Annals of Surgery* for 1898, and that of Cramp in the *Medical Record* for Jan. 16, 1915.

Most of the cases reported have been published in the British and German journals. In Kehr's "*Chirurgie der Gallenwege*," published in 1913, five cases of complete torsion are mentioned: those of Mühsam, Nehrkorn, Mayer, Fischer and Kubig. He evidently had not looked outside the German literature.

It is necessary to distinguish between partial and complete torsion. Sutter reports one case of complete torsion and two cases of incomplete torsion. The reports of Aladar Fischer, Asteriades and Seefisch discuss incomplete torsion, with which I am not directly concerned in this article. Clinically, there is a sharp distinction between the two types. In complete torsion there is strangulation of the blood supply and gangrene of the gallbladder, and the symptoms begin with dramatic suddenness. In incomplete torsion the symptoms are due to interference with gallbladder drainage, and more closely resemble those of chronic cholecystitis.

Angulation of the cystic duct is a separate condition. Krukenberg reported two such cases in 1913. He described the free gallbladder with a short mesentery and named this condition "wandering gallbladder."

The anatomic relationship of the gallbladder to the liver varies widely. Roughly, this relationship may be considered in four phases, as described here.

1. In rare cases the gallbladder is found entirely imbedded within the liver, and its surface is completely hidden. The cystic duct, however, is usually outside of the liver, and the fundus of the gallbladder is felt as a soft area in the liver, just above its anterior margin.

2. In many gallbladders a large portion of this viscus is covered by peritoneum, but some portion of the wall of the gallbladder throughout most of its length adheres to the liver, with no tissues interposed. When such a gallbladder is removed, it leaves a considerable area of denuded liver, to which some abdominal structure is likely to adhere.

3. In many cases, the gallbladder is attached to the liver throughout its length, but nowhere touches it closely. Between the gallbladder and liver a layer of fibrous tissue is interposed, forming a sort of mesentery.

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That the liver in mammals is the chief organ producing urea from cleavage products of protein metabolism and from ammonia absorbed from the alimentary canal has long been held as probable, although not so definitely proved as to go unchallenged. Folin and his co-workers have reported experiments which they interpret as showing that in mammals, uric acid, for example, is destroyed principally in the blood; but the recent work of Mann and his associates by methods of total extirpation of the liver seems to show that the liver is the main organ that forms urea and destroys uric acid. Of course, even the experiments of Mann are open to the objection that the failure to produce urea and destroy uric acid after liver extirpation may be due to indirect impairment of other tissues or changes in the blood composition. At present the latter alternative seems the least probable one. Liver perfusion experiments, as well as portal and hepatic venous blood chemistry, seem to show a considerable demidization in the liver, but this is probably not an exclusive liver function. These processes probably go on to a certain extent in every living cell in the body. While the so-called meat poisoning following high protein diet in dogs with Eck fistula indicates a definite rôle of the liver in connection with taking care of some of the immediate end-products of the protein digestion or the regulation of cellular protein metabolism, neither blood nor urinary analysis in such meat intoxication has yielded the final answer as to the precise nature of these processes or even the specific substances responsible for the symptoms of intoxication. The intoxication does not appear to be due to ammonia.

*Uric Acid Formation.*—It has been proved that uric acid is derived from the metabolism of nucleoproteins (purine bases). It is believed that the greatest bulk of the uric acid excreted from the body comes from an exogenous source and is derived from the nucleoproteins of the food. In most tissues taken as foods, the bases in the nucleins have already been partially oxidized by the action of autodigestive and oxidizing enzymes of the tissues while still in the nuclein molecule, so that they are free in the intestine in a partially oxidized form as hypoxanthine, xanthine, guanine and adenine. These bodies are absorbed at least in part. Their absorption is followed by the appearance of some uric acid in the urine. The exact locus in which all of these changes occur is not exactly known, but it is worthy of note that of the total purine ingested only a small part appears in the urine as uric acid. The experiments of Bollman, Mann and Magath have given a great deal of information concerning uric acid metabolism.

According to Bollman, Mann and Magath, large amounts of uric acid appear in the urine of dogs following hepatectomy, which also gives rise to an increase in the uric acid content of the blood. Uric acid injected intravenously into animals following hepatectomy may be almost

rate was 150. There was an inguinal hernia on the right side. Directly above the hernia a sausage-shaped tumor the size of an infant's head was felt. The patient was in a state of collapse. A diagnosis of intestinal obstruction was made. Operation disclosed a large black mass, which was thought at first, to be hydronephrosis in a wandering kidney. Further examination proved that the swelling was an enlarged and strangulated gallbladder, which was rotated twice on the cystic duct. There were four stones in the gallbladder, the walls of which were thickened and infiltrated with blood. The cavity of the gallbladder was also filled with blood. Cholecystectomy was performed. The patient collapsed on the table and died the following night.

CASE 3.<sup>3</sup>—A woman, aged 74, had suffered from attacks of sharp abdominal pain from the time she was a young girl, but she had become well in her old age. Eight days before admission to the hospital she had a sudden attack of pain in the upper part of the right side of the abdomen and in the back. Her bowels ceased to move, and she vomited. There was a great deal of resistance in the muscles of the upper part of the right side of the abdomen. Masses could not be felt. The condition was thought to be empyema of the gallbladder. When the abdomen was opened, a dark gallbladder was seen, surrounded by fine adhesions. When these adhesions were separated, torsion of the gallbladder on the cystic duct was found. There was a short band of adhesions running from the cystic duct to the liver. The gallbladder was entirely surrounded by peritoneum and was not perforated. Cholecystectomy was performed and the patient recovered.

CASE 4.<sup>4</sup>—A woman, aged 61, had an attack which began with a slight pain in the upper part of the right side of the abdomen. The bowels were regular, and there was no vomiting. The attack, which began four days before admission to the hospital, later became more severe, and there was some vomiting. There was some pain in the right shoulder. The leukocyte count was 20,000 on admission. There was marked spasm of the abdominal muscles, especially on the right side. There was great tenderness and a mass in the gallbladder region. Jaundice was not a symptom. The heart, lungs and kidneys were normal. The diagnosis was either appendicitis or gallbladder disease. When the patient was put under anesthesia, a definite pear-shaped tumor was felt, extending from the region of the umbilicus into the region of the gall-bladder. The diagnosis was then empyema of the gallbladder. When the abdomen was opened, a moderate amount of bloody serum escaped, and the gallbladder, a dark red, sausage-shaped mass, the size of a goose egg, was found to be completely twisted from right to left on the cystic duct. It was removed. The walls were infiltrated with blood, and one stone was found in it. The patient recovered.

CASE 5.<sup>5</sup>—A woman, aged 72, had a sudden attack of upper right abdominal pain three days before admission. She had not been ill previously. Jaundice was not a symptom. A round tumor could be felt in the region of the gallbladder. The condition was diagnosed as acute cholecystitis. Operation showed a gallbladder about the size of a pear. It was gangrenous and sur-

3. Nehr Korn: Gangrän der Gallenblase durch Stieldrehung, Deutsche Ztschr. f. Chir. 96:319, 1908.

4. Mühsam, R.: Stieldrehung der Gallenblase, Berl. klin. Wchnschr. 14: 1179, 1908.

5. Lett, Hugh: Two Unusual Conditions of the Gall Bladder. One a Case of Torsion, Lancet 1:1099 (April) 1909.

ascribed to a ferment. Probably the kidneys are active in changing the creatine arriving by the blood to creatinine, but it is certain that they are not the only organs having this property. The tissues are also able to destroy creatine, but what is formed from it is unknown.

The increase of creatine in the urine in diabetes and carbohydrate starvation or after the injection of thyroid extract is ascribed by Folin, Shaffer and others to the increased catabolism of the tissues, but it is also possible that it is due to the setting free of the creatine from the combination in which it occurs in the muscles. Nothing definite is known of the function of creatine in the muscles and the other organs; whether it is primarily a waste product, or whether by its presence it affects the metabolism of the tissues, is not known. Further investigations are necessary. While all the really important questions about the origin and significance of creatine and creatinine still remain unanswered, it appears that these substances hold an important place in metabolism.

TABLE 1.—*Percentage of Urinary Output of Nitrogen Bodies Under Normal Conditions*

Exogenous Source (Food)	Urine Nitrogen, per Cent	Urine Nitrogen, per Cent	Endogenous Source (Tissue Catabolism)
Proteins-amino-acids-urea.....	60	20	Tissue (muscles); ammonia-urea
Nucleoprotein-uric acid.....	99-95	5-10	Gland origin; white blood cells-uric acid
Creatinine only under forced.....	(?)	100	Creatinine (creatine conversion)

The constancy of the excretion of creatinine indicates that it is, as Folin suggested, an index of the real catabolism of the vital machinery of the body proper, in distinction from that catabolism which increases the free energy.

#### URINE NITROGEN

Under ordinary circumstances, the urinary output of nitrogen bodies is found in the following proportions: Of the total amount of urea excreted in the urine, 60 per cent is derived from the breaking down of the proteins in the food, and 30 per cent is derived from the breaking down of the proteins of the body tissues, especially of the muscles. Ninety-five per cent of the uric acid is derived from the nucleoproteins of the food; 5 per cent is derived from the metabolism of the body tissues, especially its glandular organs. Under extraordinary conditions, a large excretion of uric acid which has been experimentally proved to follow the removal of the liver, is to be interpreted clinically to indicate destruction of liver tissue. All of the creatinine can for practical purposes be assumed to be derived from tissue breakdown; in exceptional instances, when the diet contains extraordinary amounts of creatine and creatinine, increased amounts of the latter appear in the urine, being derived partially from this source.

was pain; there was a stool the evening she became ill. After this there was no movement, and there was eructation of gas and vomiting. On admission the patient's general condition was good, the pulse rate was 88. The abdomen was distended. There was pain and resistance on the right side of the abdomen; a mass could not be felt. The diagnosis was acute appendicitis. The appendix was exposed and found normal. Some fluid was seen, and the incision was enlarged upward and a gangrenous gallbladder, attached to surrounding structures by fine adhesions, was exposed. The gallbladder was twisted on the cystic duct 360 degrees from right to left (clockwise). Cholecystectomy was performed, and there was a small drain. The patient recovered.

CASE 10.<sup>10</sup>—A woman, aged 73, became ill four days before admission to the hospital with pain and constipation. When admitted she did not have fever, the abdomen was distended and a tender mass was felt under the liver. The diagnosis was ileus, thought to be due to cancer of the hepatic flexure. At operation, a gangrenous gallbladder was found twisted on the cystic duct 360 degrees. It contained one stone. Cholecystectomy was performed, and the patient recovered.

CASE 11.<sup>10</sup>—A woman, aged 64, gave a history of repeated attacks of gall-stone colic. An attack began the day before admission with severe abdominal pain, vomiting and constipation. She was in poor general condition, with abdominal distention. Under the liver a tender swelling the size of an apple was felt. The diagnosis was volvulus of the gallbladder. At operation, a large gangrenous gallbladder was found, twisted 360 degrees on the cystic duct. After cholecystectomy was performed, she recovered.

CASE 12.<sup>10</sup>—A woman, aged 78, gave a history of short attacks of abdominal pain for two years. The onset of this attack was four days before admission. She suffered sharp pain in the entire abdomen, more marked on the right side. Constipation and vomiting were symptoms. Under the margin of the liver there was indefinite tender resistance. Operation disclosed a dark red gallbladder with 180 degrees torsion on the cystic duct. It contained one stone. Cholecystectomy was performed, and the patient recovered.

CASE 13.<sup>11</sup>—A woman, aged 79, was suffering with severe pains in the abdomen. The past history was negative, except for appendicitis many years before. The onset occurred twenty-four hours before admission to the hospital. Terrific pains in the abdomen and nausea and vomiting were the symptoms. The vomitus was foul smelling and green. From that point on, she had no bowel movement and no escape of gas. The clinical diagnosis was ileus. Her temperature was normal. The pulse rate was 70 and the pulse beat was light and of good volume. The abdomen was large and flabby. Peristalsis was not visible. In the region of the gallbladder, one could feel a round, smooth, tense and tender mass, which extended three or four finger-breadths below the costal margin. There was a slight flatness on percussion, continuous with dullness in the liver. The rest of the abdomen was not tender, but was soft and flabby. The urine showed a trace of sugar, which disappeared after the operation. After an enema the patient passed some foul-smelling gas, but the foul-smelling, almost fecal-like vomiting continued. Cholecystitis with a stone in the cystic duct was considered as a diagnosis, but there were symptoms of ileus, and

10. Krabbel, Max: Die Stieltorsion der Gallenblase, *Deutsche Ztschr. f. Chir.* 154:76, 1920.

11. Hansen, P. N.: Et tilfælde af volvulus af galdeblæren, *Hospitalstid.* March 30, 1921, p. 23.

*Blood Nonprotein Nitrogen.*—Estimations of nonprotein nitrogen are utilized in some laboratories instead of estimations of blood urea. The technic for the estimation of nonprotein nitrogen is considerably more complicated than is that for blood urea. The normal blood content of nonprotein nitrogen varies approximately from 30 to 50 mg. per 100 cc. of blood. Definite figures are especially difficult to establish. Data regarding the nonprotein nitrogenous blood components have attained undeniable value in the interpretation of kidney function. They are dwelt on in the clinical laboratory of today as indexes of the degree and type of retention occurring in specific cases, and they influence both the diagnosis and the prognosis. The details of the distribution of the nonprotein nitrogenous components in the blood have been studied with respect to their bearing on nitrogen metabolism, as well as the degree of elimination of nitrogenous waste.

The accumulated data have been somewhat disappointing to many persons, notably to clinicians. They have been encouraged by the information secured from blood chemistry in respect to renal functions and the corresponding conditions of the kidney. They had come to expect that further data on nonprotein nitrogen in cases uncomplicated by adverse kidney factors might throw light on obscure diseases, particularly those having a background of metabolic disorder. Numerous laborious collections of statistics regarding the nitrogenous composition of the blood in diseases of the nervous system have failed to elucidate the pathogenesis or the pathology of the subject.

*Blood Uric Acid.*—The normal blood content of uric acid reflects the nucleoprotein content of the food from which it is normally almost entirely derived, and ranges between 1.5 and 3.6 mg. per 100 cc. of blood. In certain physiologic periods, notably the later months of pregnancy, the uric acid content of the blood rises considerably; this is a physiologic phenomenon related to pregnancy. Experimentally as referred to previously, the removal of the liver (Bollman, Mann and Magath) is followed by the accumulation of uric acid in the blood stream. A similar increase in the uric acid of the blood has been noted by Lenox to follow prolonged starvation. The exact mechanisms causing these increases is not definitely known.

Uric acid circulates in fairly constant concentration in the blood of men, any increment in the amount being indicative of a pathologic condition. Whatever the intermediate reactions may be, an increased output of uric acid is demonstrably an indication of an increased transformation of purine yielding products, whether the latter are derived from the diet or have an endogenous origin in the cells and tissues of the body. Deductions from the work of Bollman, Mann and Magath, his co-workers, referred to previously, seem to show that in liver conditions high concentrations of blood uric acid can be used as a differential point as indicating liver cell destruction.



mass was found; this was a gangrenous gallbladder. There was some fluid in the peritoneal cavity. The torsion was from left to right and ten or twelve moderately large gallstones were found. Cholecystectomy was performed, and the recovery was uneventful.

CASE 18.<sup>16</sup>—A case of torsion of the gallbladder in an old woman, which was diagnosed cholelithiasis, is reported. In the region of the gallbladder there was a large pear-shaped tumor. The attack came on sharply with pain. At operation an enormous, movable and elongated gallbladder with a narrow mesentery was found. The gallbladder was twisted on the cystic duct. Cholecystectomy was performed and the patient recovered.

CASE 19.<sup>17</sup>—A woman, aged 74, had frequent attacks of abdominal pain for a year preceding the operation. On Aug. 20, 1924, following a hard day's work in the field, she had sudden violent abdominal pain accompanied by vomiting. During the following days there was some improvement, then a new attack of pain with vomiting. On August 26, six days later, the patient was transferred to the hospital. In the upper right quadrant a sausage-shaped tumor was felt. Jaundice was not a symptom. This tumor was smooth and mobile, and was the size of a fist. At operation, a bluish-red, tight, spastic swelling was seen. It was a gangrenous gallbladder, twisted on its pedicle 360 degrees (counter-clockwise) and attached to the liver by a pedicle. When it was removed, an elongated pedicle with a cystic area was found buried in adhesions and was removed with difficulty; it was thought to be a distended cystic duct. Rapidly developing jaundice followed the operation, and the patient died twelve days later. At autopsy it was found that the pull on the gallbladder had elongated the common and hepatic ducts, and these had been ligated when the gallbladder was removed.

CASE 20.<sup>18</sup>—A woman, aged 54, had a sudden attack of severe pain in the upper part of the right side of the abdomen with frequent vomiting. It was the first attack. Jaundice was not present. Tenderness and rigidity in the upper part of the right side of the abdomen were pronounced, and a round lump suggestive of an enlarged gallbladder, could be felt. The preoperative diagnosis was acute cholecystitis with a stone impacted in Hartmann's pouch. At operation, some serous fluid escaped when the abdomen was opened, and a black distended gallbladder was presented. It was completely covered by peritoneum and attached by its proximal end to the liver by a mesentery, which contained the cystic duct and the blood vessels. A peritoneal fold ran from the cystic duct to the duodenum. There was one complete revolution of the gallbladder from right to left. The gallbladder contained bile mixed with blood, and its walls were much thickened by hemorrhagic infiltration, but it did not contain stones.

CASE 21.<sup>19</sup>—Marinacci reports a patient with a tumor mass in the position of the gallbladder. The tumor was rather low. A twisted ovarian cyst was suspected on account of the sudden appearance of the symptoms. Operation revealed an enlarged, distended gallbladder with very little liver attachment. The gallbladder was twisted on the cystic duct. A portion of the gallbladder

16. Dubs, J.: Ein Fall von Torsion der Gallenblase, Schweiz. Med. Wchnschr. 3:93 (Jan. 17) 1924.

17. Sutter, A.: Torsion of Pedicle of the Gall Bladder, Beitr. z. klin. Chir. 133:519-532 (March) 1925.

18. Fifield, L. R.: Torsion of Gall Bladder, Brit. M. J. 1:920, 1925.

19. Marinacci, Sertorio: Torsion of the Gall Bladder, Acute Dropsy, Policlinico 33:194 (Feb. 8) 1926.

TABLE 2.—Cases with Mechanical Defect (Hernia) but Otherwise in an Apparently Normal State of Health

Case	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
1.....	12.6	27.3	3.5	1.0
2.....	17.6	33.3	3.5	1.1
3.....	18.2	35.0	3.4	1.1
4.....	14.0	30.0	2.5	1.1
5.....	....	34.1	2.5	1.0
6.....	11.2	....	3.5	1.0
7.....	18.2	34.1	1.7	1.0
8.....	15.4	33.3	3.3	1.2
9.....	14.0	....	2.3	1.2

TABLE 3.—Cases with Mechanical Defect (Postoperative Adhesions) with Various Grades of Symptoms but Without Signs of Interference with the Movement of the Intestinal Content—Without Nephritis and in Otherwise Good Physical Condition.

Case	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
1.....	14.0	33.3	4.0	1.2
2.....	12.6	34.1	2.0	1.1
3.....	12.6	29.3	1.6	1.2
4.....	11.2	....	3.0	1.1
5.....	12.5	21.3	...	0.75
6.....	21.25	42.5	...	1.25

TABLE 4.—Cases in a Physiological Period (Pregnancy) Occurring Normally and Without Abnormal Symptoms

Case	Month	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
39.....	6	11.0	21.0	1.1	1.1
40.....	8	8.5	22.5	2.2	1.2
41.....	3	10.0	23.0	1.5	1.1
42.....	8	10.0	24.0	2.5	1.3
43.....	5	11.0	25.0	1.9	1.3
44.....	7	9.5	23.7	2.3	1.3
45.....	7	17.0	25.0	1.9	1.3
46.....	8	11.0	15.0	2.2	1.3
47.....	4	9.0	25.0	Trace	1.3
48.....	9	15.0	25.0	Trace	1.6
49.....	6	10.0	25.0	2.3	1.3
50.....	3	10.0	22.5	2.3	1.1
51.....	7	12.0	30.0	2.2	1.2
52.....	4	10.7	22.5	2.6	1.5

TABLE 5.—Chronic Diseases (Malignancy, etc.) in Elderly People Without Manifestations Referable to any Change or Disturbance of Metabolism

Case	Diagnosis	Urea Nitrogen	Nonprotein Nitrogen	Uric Acid	Creatinine
1	Gangrene of foot.....	16.5	35.3	1.5	1.7
2	Gangrene of foot.....	11.2	30.7	2.5	1.3
3	Carcinoma of stomach.....	12.6	34.1	2.5	1.6
4	Calcified fibromuscular tumor.....	21.0	42.0	4.0	1.2
5	Hyperostosis of.....	27.5	37.5	2.7	1.0
6	Postoperative abdominal pain.....	14.0	37.6	3.0	1.5

operation, but developed a deep jaundice afterward. At autopsy it was seen that the pull of the gallbladder had elongated the common and hepatic ducts, and these structures had been included in the ligature.

All the patients were women, except two. Kubig's case occurred in a man, aged 73. This man had been a patient in the Tuberculosis Pavillion, and the condition of the gallbladder was not suspected before the autopsy. The other man was Cramp's patient. The evidence is conclusive that this condition is usually seen in older women, who are thin and relaxed, and who belong to the narrow, long-bodied type with more or less downward displacement of the abdominal organs. It would be interesting to find out the percentage of free gallbladders in persons of this type.

The gallbladder exhibited different degrees of necrosis in twenty cases, the only exceptions being Wendel's and Kubig's patients, in whom the torsion was somewhat less than 360 degrees. Both of these cases might be omitted from the list of complete torsion of the gallbladder.

The direction of the volvulus is apparently not a matter of significance; of the twenty-two cases, seven were clockwise, five were counter-clockwise, and in ten cases the direction was not mentioned.

In all cases of the series, except those of Kubig and Marinacci, the onset was sudden, with pain in the upper part of the right side of the abdomen as the outstanding symptom. Vomiting was fairly constant, so much so that in three cases ileus was suspected.

In these cases of torsion of the gallbladder most of the surgeons have reported the presence of a moderate amount of bloody serous fluid in the peritoneal cavity. This was true of my own case.

In almost every instance the gallbladder lay free in its bed. In a number of cases there were loose, thin, recent adhesions, but the delivery and removal of the gallbladder was uniformly not difficult.

There was little evidence of peritonitis. The outstanding pathologic condition was necrosis due to strangulation of the blood supply, and the only peritoneal involvements were the loose adhesions and the small quantity of bloody serum.

In the reports of this series of cases it was repeatedly mentioned that examination of the gallbladder showed its walls to be thickened and infiltrated with blood, and the cavity of the gallbladder was usually filled with blood also. The gallbladder was nearly always enlarged, was distended, smooth and elastic, and, in a number of instances, was somewhat curved, being described as either kidney-shaped or sausage-shaped.

In only one instance was the correct diagnosis made before operation, Krabbel's second case. In thirteen of the twenty-two cases a mass in the upper part of the right side of the abdomen was felt, and in eight

The faculty for making use of various materials for producing the same end-product gives rise to compensatory powers which frequently keep the blood index at normal levels when pathologic conditions are present in which one is accustomed to find differences in the blood indexes.

Multiplicity of methods and mechanisms whereby similar metabolic changes can occur in different regions of the body give ample opportunity for wide compensatory powers; wide reserve powers are thereby created; all of these give opportunity for additional variation.

It seems correct to assume from these observations that in any given case a normal must be established for each person at the moment of examination. Single observations are of little moment; a series of observations are necessary. Comparisons of persons and of disease can be made only from comparable series of observations taken under normal and abnormal conditions; actual figures mean less than similar plus or minus changes viewed in the light of repeated observations and of actual pathologic conditions and controlled by a knowledge of the underlying opposing factors the resultants of which form the balance to be found in the blood stream. Abnormalities are to be determined only along these lines and according to these criteria.

# CARDIAC OUTPUT IN THE DOG DURING ETHER ANESTHESIA

## III. THE EFFECT OF THERAPEUTIC AMOUNTS OF DIGITALIS ON CARDIAC OUTPUT OF THE ANESTHETIZED DOG \*

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In previous communications,<sup>1</sup> evidence has been presented to show that when ether is administered to the correct degree for surgical anesthesia, it causes an increase in the cardiac output, and that this increase is not so great after alkali has been injected as before. It was concluded from this work that a large part of the increase in the cardiac output of the heart during ether anesthesia was caused by an increase in the hydrogen ion concentration of the blood. However, the less marked but definite increase in the cardiac output of the anesthetized dog following the injection of alkali suggests that part of the increase must be ascribed to a direct stimulating action of ether on the heart.

Harrison and Leonard<sup>2</sup> have shown recently that digitalis decreases the cardiac output of dogs, and their evidence indicates that this is accomplished primarily through the production of an increased tonicity of the heart. The effects on the contractility were believed to be secondary to changes in the tonus. It is generally conceded that digitalis exerts its beneficial effect by action on the heart itself, regardless of whether this is accomplished through changes in the cardiac output or through a restoration of balance between the ventricles. Eppinger, von Papp and Schwarz<sup>3</sup> reported a decrease in the cardiac output in one patient following the administration of digitalis. Studies by indirect methods by many observers have indicated that digitalis increases the output of the heart in animals that have had various operative procedures performed; but concerning the effect on the normal dog, the work of Harrison and Leonard seems conclusive.

The purpose of the present study was to determine the effect of ether anesthesia on the cardiac output of the digitalized dog. This was undertaken with two objects in view: (1) to attempt to gain further information as to what direct stimulating action ether has on the heart

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\* From the Department of Surgery, Vanderbilt University.

1. Blalock, A.: The Effect of Ether Anesthesia on the Cardiac Output of the Dog. *Arch. Surg.* 14:732 (March) 1927. The Effect of the Injection of Alkali on the Cardiac Output of the Anesthetized Dog. *Ibid.* 14:921 (April) 1927.

2. Harrison, T. R., and Leonard, B. W.: The Effect of Digitalis on the Cardiac Output of Dogs. *J. Clin. Investigation* 3:1 (Oct.) 1926.

3. Eppinger, Hans; von Papp, L., and Schwarz, H.: *Asthma Cardiale*, Berlin, Julius Springer, 1924, p. 191.

The blood vessels run in this layer, and it is covered in front and behind by the peritoneum, which is reflected over it from the gallbladder to the liver. Such a gallbladder is usually freed with little difficulty from the liver and leaves a relatively narrow area of denudation, which is easily covered.

4. The last group includes uncommon cases in which the entire gallbladder is covered by peritoneum, and is free. The gallbladder is attached to the liver by a short mesentery which extends along the cystic duct and usually terminates near the point where the cystic duct joins the gallbladder. In this mesentery are the cystic vessels. It is in cases of this kind that torsion of the gallbladder occurs. There is considerable medical literature calling attention to this condition.

In 100 autopsies, Brewer found that the gallbladder had a mesentery-like attachment in five cases. In another report Ssuslow mentions six similar mesenteries in 145 persons examined. Jacquement found it twice in 200 patients; Raynal twice in thirty-six.

I have found in the literature twenty-one cases of complete torsion of the gallbladder, to which is added the case of my patient. A brief synopsis of these cases follows.

#### REPORT OF CASES

CASE 1<sup>1</sup>—A woman, aged 23, had been under observation from November, 1895, until March, 1897. In November, 1895, a mobile ovoidal tumor was found in the upper right quadrant. The tumor was about 2 inches (5.08 cm.) long and 3 inches (7.6 cm.) wide, and was cystic in nature. The right kidney was loose, and could be moved as far as the umbilicus. The patient refused to submit to an operation. She was treated, and declared herself well until Sept. 20, 1896, when she was suddenly seized with severe pain in the upper part of the right side of the abdomen, with vomiting, high fever and abdominal distention. At this time the cystic swelling could not be felt. There was a fixed, rigid, painful swelling in its position. The woman again refused to submit to an operation and soon recovered from the attack. In the early part of March, 1897, she returned to the hospital, saying that she was two months pregnant. On March 25, 1897, she was operated on. At operation, perforated cholecystitis, cholelithiasis and a peritoneal abscess were found. Two hundred and thirteen gallstones and the gallbladder were removed. The gallbladder was not gangrenous, but was much twisted on the cystic duct. It was adherent, but the adhesions were recent. The cystic duct was  $3\frac{1}{4}$  inches (8 cm.) long, with a mesentery about 2 inches (5 cm.) long, attached to the inferior surface of the liver. The neck of the gallbladder was obstructed by the largest stone. The patient recovered.

CASE 2<sup>2</sup>—A woman, aged 54, became ill two days before coming to the hospital, with a sharp pain in the abdomen. The condition was not accompanied by vomiting. When she was admitted the abdomen was rigid and her pulse

1. Wendt, A. V.: A Case of Floating Gall Bladder and Kidney Complicated by Cholelithiasis with Perforation of the Gall Bladder, *Ann. Surg.* 27:192, 1898.  
2. Mayer, W.: Ein weiterer Fall von Stieltorsion der Gallenblase, *Berl. Klin. Wochenschr.* 14:162, 1908.

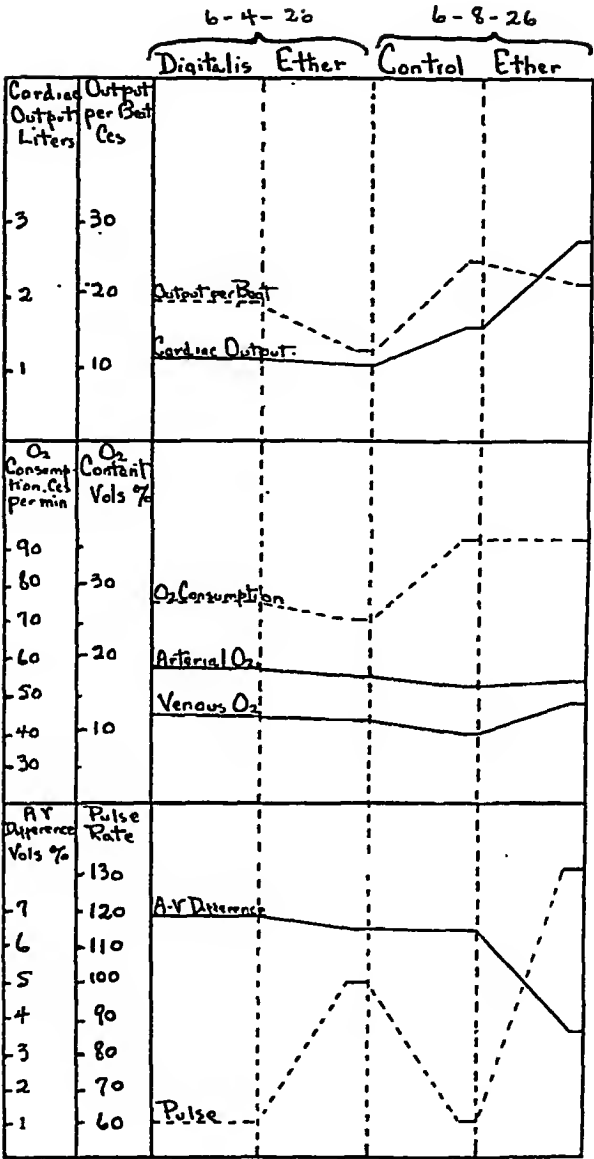


Chart 1.—The cardiac output of the digitalized dog remained about the same during ether anesthesia. Four days later, the output increased markedly during ether anesthesia. No digitalis was given during this interval. The oxygen consumption was higher after the effects of digitalis had disappeared. The coefficient of utilization changed little during an ether anesthetic seven and one-half hours after digitalis had been given, but decreased greatly when the dog was anesthetized four days later.

The drawings are purely schematic; time relations are neglected.

rounded by recent adhesions, which were separated with the finger. There was complete axial rotation of the gallbladder on the cystic duct from left to right (counter-clockwise). The gallbladder was free, with a short mesentery. Gallstones were not present. Cholecystectomy was performed, and the patient died twelve hours later.

CASE 6.<sup>6</sup>—A woman, aged 70, two days before she came to the hospital, had an attack which began with pain in the abdomen, like that of acute appendicitis. She vomited and there was an elevation of temperature. Her tongue was dry and coated, and her whole abdomen was tender. Tenderness and rigidity were most marked in the right upper quadrant. A diagnosis of acute appendicitis with abscess or cholecystitis was made. When the abdomen was opened, a considerable quantity of bloody serum escaped. The appendix was normal. A large, bluish mass, the size of a goose egg, was found to be the gallbladder. It was attached to the liver only by a twisted pedicle and was covered with a grayish exudate. The twist was 360 degrees (counter-clockwise), and was entirely on the cystic duct. Stones could not be felt in the common duct. Bloody serum was present. The gallbladder was not ruptured. It was removed, and the patient recovered.

CASE 7.<sup>1</sup>—This was a case of volvulus of the gallbladder found at autopsy in the body of a man 73 years old. During his last illness, he had a severe cough. He died in the Tuberculosis Pavillion. At autopsy profuse bronchitis and hyperemia of the lungs, bronchopneumonia and torsion of the gallbladder with circumscribed peritonitis were found. The gallbladder was twisted clockwise on the cystic duct 270 degrees, was dark blue and was free. There were no gallstones, and the gallbladder was not gangrenous or thickened. It was entirely covered with peritoneum.

CASE 8.<sup>7</sup>—At a meeting of the New York Academy of Medicine in the Section on Surgery, held Dec. 4, 1914, Dr. Cramp presented a patient, who had been admitted to Bellevue Hospital suffering from pain in the abdomen, nausea and vomiting. This patient was a man whose age was not given. From the history of the case it was supposed that his trouble was due to indiscretion in diet, and he was placed in the medical division. A tentative diagnosis of gastritis was made. The following day he was transferred to the surgical division. There was rigidity over the right upper quadrant and a temperature of 99 F., but the symptoms did not indicate obstruction. There was a high leukocyte and polymorphonuclear count, and an epigastric tumor. Immediately after the incision was made, the gallbladder protruded through the opening. It was black and twisted one and one-half times from right to left on its pedicle. It did not communicate with the liver, except toward the common duct. Dr. Cramp presented the specimen removed, which did not resemble a gallbladder whatever. Cholecystectomy was performed, and the patient recovered.

CASE 9.<sup>8</sup>—A woman, aged 71, was taken suddenly ill three days before admission to the hospital. She had not had a previous attack. The first symptom

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6. Fischer, August: Ein weiterer Fall von Stieltorsion der Gallenblase, Berl. klin. Wchnschr. 18:1784, 1910.

7. Kubig, G.: Ueber Volvulus der Gallenblase, München. med. Wchnschr. 9:1998, 1912.

8. Cramp, Walter C.: Gangrene of Gall Bladder from Twisted Cystic Duct, Med. Rec. 87:120 (Jan. 16) 1915.

9. Reichel: Volvulus der Gallenblase, München med. Wchnschr. 3:884 (Aug. 1) 1919.



TABLE 1.—*The Effect on the Cardiac Output of Ether and of Digitalis and Ether*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Per Cent Saturation	$p_{\text{H}}$	Oxygen Consumption, Cc. per Minute	Cardiac Output, Cc. per Minute	Output per Kg. per Minute, Cc.	Output per Beat, Cc.
5/12/26: Control study, $\frac{3}{4}$ grain morphine .....	8.6	99	70	15.36	8.83	6.48	17.1	90	7.35	73.95	1,141	132.7	16.3
5/12/26: After 7 minutes ether .....	8.6	99	150	14.04	11.04	3	17.22	82	7.29	59.04	1,968	228.9	13.1
5/12/26: After additional ether .....	8.6	99	150	14.40	11.40	3	.....	..	7.30	58.4	1,917	226.4	13.0
5/12/26: 2 hours after stop-plug ether .....	8.6	98.5	70	15.24	8.63	6.53	.....	..	7.36	75.64	1,148	133.4	15.1
5/15/26, 2 p. m.: Control study, $\frac{3}{4}$ grain morphine .....	8.2	101	120	13.8	6.97	6.83	14.6	94.5	....	62.52	915	111.5	7.6
5/15/26, 3:15 p. m.: After 6 minutes anesthesia .....	8.2	101	180	11.51	8.36	3.15	17.0	68	....	57.2	1,810	221	10.1
5/15/26, 10:30 p. m.: $\frac{6}{16}$ hours after 4.2 cc. of a digitalis preparation ....	8.2	100.6	210	13.2	4.85	8.35	15.02	89	....	88.15	1,056	128.7	5.02
5/15/26, 11:55 p. m.: After 7 minutes anesthesia ....	8.2	100.6	225	11.26	5.70	5.56	13.6	83	....	60.88	1,095	133.5	4.9
5/16/26, 11:30 a. m.: 20 hours after digitalis preparation .....	8.1	101	210	11.22	4.20	7.02	11.31	99	....	82.0	1,168	144	5.5
5/16/26, 2 p. m.: After 7 minutes anesthesia .....	8.1	99.6	220	10.08	5.65	4.43	12.48	87	....	61.0	1,377	170	6.3
5/16/26, 5:15 p. m.: After 75 minutes anesthesia ....	8.1	97.6	225	9.08	3.60	6.20	11.4	83	....	66.4	1,071	132	4.7

Protocol: 5/12/26: A control study was performed after three fourths grain (0.04 Gm.) of morphine was given. The dog was then given ether anesthesia through a mask for seven minutes until the eye reflexes were barely abolished, and determination of the output were made. The ether was discontinued for a short period; ether was again administered for seven minutes, and the output was determined. The eye reflexes were abolished. Two hours after the anesthetic was stopped, a second control study was made.

5/15/26: At 2:00 p. m., a control study was made after three fourths grain (0.04 Gm.) of morphine was given. Ether anesthesia was begun at 3:15 p. m., and determinations were made six minutes later, the eye reflexes being abolished at the time the specimens of blood were obtained. At 4:00 p. m., the animal was given 4.2 cc. of a digitalis preparation. At 10:30 p. m., six and a half hours following the giving of the drug, one half grain of morphine (0.03 Gm.) was given, and control studies were made. At 11:55 p. m., anesthesia was given for seven minutes, eye reflexes were abolished, and the determinations were made.

5/16/26: At 11:30 a. m., twenty hours following the giving of a digitalis preparation, one half grain of morphine (0.03 Gm.) was given, and control studies were made. At 2:00 p. m., anesthesia was given for six minutes, eye reflexes were abolished, and control determinations were made. At 5:15 p. m., determinations were made after anesthesia for one hour and fifteen minutes, and the eye reflexes were abolished. The pulse was regular and rapid.

this led to immediate operation. As soon as the peritoneum was opened, a thin, serous, bloody fluid exuded. A mass, which resembled an incarcerated or tortuous gangrenous intestine, appeared, but it was seen at once that it was not related to the intestine. The pedicle of the gallbladder was rotated 360 degrees clockwise. The pedicle was 3 cm. or 4 cm. wide, was thin and contained few veins, but nothing else was clearly defined. The pedicle stretched along the edge of the liver, and the liver was at that point atrophic, with some thickening of the serosa. The rest of the liver was irregular, with deep scars. The gallbladder and cystic duct did not contain stones. The gallbladder was directly continuous with the thick serous membrane of the gallbladder. The gallbladder and cystic duct did not contain stones. The gallbladder was divided into two parts by a stricture, and it was shaped like an hour-glass. Only the fundal part was strangulated. The fundus had definite motility, and this portion was free without mesentery. The patient recovered.

CASE 14.<sup>12</sup>—A woman, aged 42, had been examined and treated for stomach trouble. The onset of her illness was sudden, with severe colicky pains in the abdomen, constipation and vomiting. She did not have fever. Under the influence of morphine and hot dressings the pain subsided, and a mass was felt on the right side, extending from the region of McBurney's point to the epigastrium. Examination was difficult, because the patient was fat and had a thick abdominal wall. She did not have jaundice. Her pulse rate was 108, and her temperature 38.2 C. The preoperative diagnosis was acute cholecystitis with hydrops. When the abdomen was opened, some serum was found. The gallbladder was surrounded by recent adhesions and was seen as a large mass. There was a band of adhesions running from the upper surface of the gallbladder toward the stomach and colon. This was cut between ligatures. The gallbladder was easily lifted from its bed and was free, except that it was attached to the liver by the cystic duct, on which it was twisted 180 degrees. The gallbladder was dark red and contained one large stone. Cholecystectomy was performed, and the patient recovered.

CASE 15.<sup>13</sup>—A woman, aged 34, had had attacks of biliousness since girlhood. The onset of the present illness was acute. She did not have jaundice, distention or visible peristalsis. Masses could not be felt. Tenderness and muscle spasms were observed. At operation, a gangrenous gallbladder was found about the size of a small hen's egg. There was one complete revolution (clockwise). Stones were not found and mesentery and peritoneal covering were not reported on. Cholecystectomy was followed by complete recovery.

CASE 16.<sup>14</sup>—A woman, aged 62, suffered a sudden colicky pain in the upper part of the abdomen. The right part of the abdomen was rigid, and a tumor could not be felt. At operation, the gallbladder was found to have rotated completely from right to left. It was free, with a short mesentery. It did not contain stones. Cholecystectomy was performed and the recovery was uneventful.

CASE 17.<sup>15</sup>—A woman, aged 67, suddenly became ill. A sausage-shaped tumor was felt in the region of the gallbladder. At operation, a reddish-black

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12. Strauss, M.: Die Stielderhung der Gallenblase, Beitr. z. klin. Chir. 122: 322, 1921.

13. Irwin, S. T.: Torsion of the Gall Bladder, Brit. J. Surg. 9:310 (Oct.) 1921.

14. Frankau, C. H. S.: Torsion of the Gall Bladder, Brit. J. Surg. 10:301 (Oct.) 1922.

15. Jonas, H. C.: A Case of Torsion of the Gall Bladder, Brit. M. J. 1:1016, 1923.

TABLE 2.—*The Effect on the Cardiac Output of Ether and of Digitalis and Ether*

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, Volume	Venous Carbon Dioxide, Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. per Minute, Ce.	Output per Beat, Ce.
5/25/26, 8:15 a. m.: Control study .....	10.5	102	90	19.16	13.55	5.61	34.46	37.72	.....	103.3	1,841	175	20
5/25/26, 4 p. m.: After ether for 17 minutes .....	10.5	102	215	20.60	16.69	3.91	24.44	23.08	.....	99.6	2,547	242	12
5/25/26, 4:00 p. m.: Control study .....	10.5	101.6	108	19.11	12.63	6.49	.....	.....	.....	118.1	1,820	173	17
5/26/26, 10:20 p. m.: 6 hours after 5.5 cc. digitalis preparation .....	10.5	104.4	95	17.35	11.88	5.47	34.30	38.45	.....	125.5	2,255	218	24
5/26/26, 11:55 p. m.: Ether 35 minutes .....	10.5	104	200	18.00	10.45	7.61	26.26	30.83	18.23	118.1	1,552	148	8
5/27/26, 2:30 p. m.: 22 hours after digitalis .....	10.1	104	125	16.4	9.31	7.09	35.91	40.20	99%	147.6	2,082	206	17
5/27/26, 4:15 p. m.: 15 minutes ether .....	10.1	102	220	18.16	12.97	5.19	31.49	34.17	18.26 99%	103.3	1,990	197	9

Protocol: 5/25/26: A healthy dog was used. At 8:15 a. m. control determinations were made without morphine. An attempt was then made to anesthetize the dog by giving ether and cotton seed oil per rectum. This was unsuccessful. At 3:45 p. m., the dog was given ether by mask for seventeen minutes before specimens of blood were taken; eye reflexes were barely obtainable. 5/26: At 4:00 p. m., a control study was made without morphine; the animal was given 5.5 cc. of a digitalis preparation after determinations. At 10:30 p. m., six hours following the giving of a digitalis preparation, determinations were made. At 11:55 p. m., determinations were made after thirty-five minutes of ether anesthesia; eye reflexes were present. The animal began to move about four minutes after the ether was stopped. 5/27: Twenty-two hours following the giving of digitalis, at 2:30 p. m., determinations were made without ether. At 4:15 p. m., determinations were made after ether anesthesia for fifteen minutes; the eye reflexes were not abolished.



TABLE 3.—*The Effect on the Cardiac Output of Ether and of Digitalis and Ether*

Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. per Minute, Ce.	Output per Beat, Ce.
Date												
10.2	98.5	60	18.48	11.76	6.72	38.19	39.97	.....	75.61	1,125	110.3	18.7
10.2	97.2	100	17.88	11.58	6.30	37.10	42.15	10.74 97%	70.11	1,113	109.1	11.1
9.8	99.5	60	15.98	9.66	6.32	38.78	41.36	.....	92.2	1,450	140	21.3
9.8	97.6	132	16.58	13.0	3.58	39.95	40.82	17.47 95%	92.2	2,771	282.8	21

Protocol: 6/1/26: At 2:00 p. m., a healthy dog was given 6.5 cc. of a digitalis preparation. At 8:30 p. m., it received 1 grain (0.06 Gm.) of morphine. At 9:30 p. m., the dog was perfectly quiet and the earline output was determined. At 10:30 p. m., determinations were made after administration of ether for twenty-five minutes. The eye reflexes were not abolished. 6/8/26: At 2:30 p. m., the animal received 1 grain (0.06 Gm.) of morphine. At 3:40 p. m., the earline output was determined. At 4:50 p. m., the output was determined after ether had been administered for thirty minutes. The eye reflexes were not abolished.

TABLE 4.—*The Effect on the Cardiac Output of Ether and of Digitalis and Ether*

Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. per Minute, Ce.	Output per Beat, Ce.
Date												
14	103	84	15.8	10.96	4.84	41.50	43.09	.....	151.29	3,126	223.3	37.2
14	102.6	210	15.8	13.36	2.44	23.33	24.60	.....	125.40	5,142	367	21.4
11	102.4	120	17.69	10.41	7.28	38.62	43.76	.....	121.77	1,673	118.2	14
14	103	180	18.04	11.01	6.10	26.10	30.18	18.10 99.7%	121.77	1,966	143	11
14	102.6	210	15.69	10.3	5.39	24.12	27.54	.....	129.15	2,306	171	11.4

Protocol: 6/12/26: At 2:30 p. m., control studies were made on a trained dog without the use of morphine. At 3:00 p. m., ether anesthesia was begun. At 5:00 p. m., determinations were made during ether anesthesia, eye reflexes being barely obtainable. 6/13: At 11:30 a. m., control determinations were made twelve and a half hours following the injection of 7 cc. of a digitalis preparation. At 2:00 p. m., ether anesthesia was begun. At 2:35 p. m., determinations were made during ether anesthesia, eye reflexes were barely obtainable. At 4:00 p. m., determinations were made, two hours following the beginning of the ether anesthesia. The eye reflexes were barely obtainable.



TABLE 5.—The Effect on the Cardiac Output of Ether and of Digitalis and Ether

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Capacity, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. per Minute, Ce.	Output per Beut, Ce.
6/20/26, 3:20 p. m.: Control study	8.5	99.8	100	18.08	10.11	7.97	36.72	42.66	.....	67.65	849	100	8.5
6/20/26, 3:55 p. m.: After 50 minutes anesthetic	8.5	99	110	18.91	11.41	7.50	34.43	38.88	10.0 99%	71.75	527	113	7
7/1/26, 5:10 p. m.: 24 hours after digitalis preparation	8.5	99	72	18.70	12.13	6.66	40.10	42.80	.....	61.5	923	109	13
7/1/26, 6:05 p. m.: After 15 minutes anesthetic	8.5	210	53.6	14.87	6.42	8.45	39.05	42.23	.....	61.5	728	86	8

Protocol: 6/20/26: At 2:00 p. m., three fourths grain (0.04 Gm.) of morphine was given. At 3:20 p. m., control study was made. At 3:45 p. m., ether was begun. At 4:30 p. m., eye reflexes were abolished, and specimens of blood were drawn. At 5:00 p. m., the dog was given 5 cc. of a digitalis preparation. 6/31/26: At 1:00 p. m., three fourths grain (0.04 Gm.) of morphine was given. At 5:10 p. m., twenty-four hours after a digitalis preparation was given, control studies were made. At 5:30 p. m., ether anesthesia was begun. At 6:00 p. m., eye reflexes were abolished, and specimens of blood were drawn.

TABLE 6.—The Effect on the Cardiac Output of Ether and of Digitalis and Ether

Date	Weight, Kg.	Temperature, Fahrenheit	Pulse Rate per Minute	Arterial Oxygen, per Cent by Volume	Venous Oxygen, per Cent by Volume	Arterio-venous Difference, per Cent by Volume	Arterial Carbon Dioxide, per Cent by Volume	Venous Carbon Dioxide, per Cent by Volume	Oxygen Consumption, Ce. per Minute	Cardiac Output, Ce. per Minute	Output per Kg. per Minute, Ce.	Output per Beut, Ce.
7/19/26, 3:00 p. m.: Control study, morphine $\frac{1}{2}$ grains	13.5	102	60	8.40	3.90	4.50	39.16	42.61	97.2	2,182	158	35.5
7/19/26, 3:50 p. m.: After ether for 35 minutes	13.5	101.6	120	8.72	0.27	2.45	39.02	42.24	86.4	3,527	263	20.3
7/23/26, 2:15 p. m.: 14 hours after 0.5 cc. digitalis preparation	13	100.8	50	9.31	4.71	4.60	.....	.....	90.0	1,657	151	39
7/23/26, 3:50 p. m.: After 35 minutes ether	13	101	120	8.72	5.30	3.42	36.12	37.99	78.0	2,281	175	19
7/23/26, 4:25 p. m.: After 70 minutes ether	13	101	135	8.60	4.71	3.89	.....	.....	75.6	1,913	149	14

Protocol: 7/19/26: At 2:00 p. m., three fourths grain (0.04 Gm.) of morphine was given. At 3:00 p. m., the animal was quiet, and control determinations were made. The dog looked perfectly well but was unnele, the cause of which was undetermined. At 3:15 p. m., ether anesthesia was begun. Specimens of blood were drawn at 3:50 p. m. after thirty-five minutes of anesthesia, the eye reflexes were abolished at the time. 7/23: At 12:15 p. m., a digitalis preparation, 0.5 cc., was given. At 1:30 p. m., three fourths grain (0.04 Gm.) of morphine was administered. At 2:15 p. m., control determinations were made. At 3:15 p. m., ether anesthesia was begun. At 3:50 p. m., the eye reflexes were abolished and specimens of blood were drawn for determinations. At 4:25 p. m., the eye reflexes were abolished, and determinations were made after anesthesia for seventy minutes.

itself, since it has been shown that digitalis decreases the output of the heart and ether increases it somewhat even in the presence of an alkaline  $pH$ ; (2) to determine whether there is experimental justification for the use of digitalis previous to operations under ether anesthesia.

### METHOD

Only the essential features of the method which was used will be described, since a detailed description has been given in the report on the effect of ether anesthesia on the cardiac output.

Thirty-six determinations of the cardiac output were made in six dogs. Two of the animals were trained and remained quiet without a sedative. The remaining four dogs were given morphine, 0.04 to 0.06 Gm., about an hour before the experiment was begun. Similar results were obtained with and without the use of morphine.

In five of the six experiments, control studies were performed before digitalis was given in order to determine the effect of ether anesthesia on the cardiac output. In the remaining experiments the effect of a digitalis preparation and ether anesthesia on the cardiac output was first determined, and the control figure for ether alone was obtained four days later. The time interval separating the intramuscular injection of digitalis and the determinations under ether anesthesia varied from six to twenty-two hours. Harrison and Leonard<sup>2</sup> found that the maximum reduction in cardiac output occurred six hours after administering a "full therapeutic" dose of digitalis preparation, and that it lasted for about forty-eight hours. The amount of the drug used was approximately the same as that employed in their experiments, i. e., fifteen cubic centimeters of digitalis preparation per kilogram of body weight. Pardee's<sup>4</sup> observations indicate that this amount represents the full therapeutic dose.

The animal was placed on a table in the dorsal position. The oxygen consumption was determined by use of a Benedict spirometer with the graphic recording device. Arterial blood was obtained by puncture of the left ventricle or femoral artery; venous blood was obtained by puncture of the right ventricle. The oxygen and carbon dioxide contents of the blood were determined. The circulatory minute volume was calculated from the Fick formula:

$$\frac{\text{Cc. O}_2 \text{ consumed per minute}}{\text{Amount O}_2 \text{ taken up in lungs by 1 cc. of blood}} = \frac{\text{Number of cc. of blood flowing through the lungs per minute}}{\text{per minute}}$$

After the control determinations had been made, ether was administered through an open cone. Variations in the depth of anesthesia are listed in the protocols, but usually the lid reflexes were abolished at the time that the specimens of blood were drawn. The method of Austin<sup>5</sup> was employed for determining the carbon dioxide content in the presence of ether.

### RESULTS

Both the trained animals and those that had undergone morphinization remained quiet throughout the experiments, and the results were essentially the same with and without the use of morphine.

4. Pardee, H. E. B.: Hypodermia Digitalis Preparations, *J. A. M. A.* 85:1359, (Oct. 31) 1925.

5. Austin, J. H.: Estimation of Carbon Dioxide in Serum in Presence of Ether by Van Slyke Method, *J. Biol. Chem.* 61:345 (Sept.) 1924.



the heart, whereas it is possible that the administration of alkali, though tending to prevent cardiac strain, may lead to untoward effects elsewhere in the body.

In this connection it is emphasized that the full therapeutic dose of digitalis was given in these experiments, and if a similar effect is to be expected in patients, doses of similar size are indicated. Such a dose is approximately 1.5 Gm. of a powdered leaf of average strength, or fifteen cubic centimeters of a digitalis preparation per hundred pounds of body weight. In order to increase the margin of safety, it seems wiser to administer two thirds of this amount in divided doses the day previous to operation.

#### SUMMARY AND CONCLUSIONS

The effect of ether on the cardiac output of six digitalized dogs was determined. Four of the animals received morphine previous to the studies, while two of the animals were trained and did not require morphine. Whereas the average elevation in the cardiac output during ether anesthesia previous to the administration of digitalis was 64 per cent, that in the digitalized dog was only 7 per cent. Further evidence is presented to show that part of the increase in the cardiac output during ether anesthesia is caused by a direct stimulating action of ether on the heart.

These observations offer a rational experimental basis for the belief that the preoperative administration of digitalis may be of considerable value in the preparation of certain types of patients for operation under general anesthesia. They also suggest that this drug should not be used during shock following operations.

The changes which were encountered during the control anesthetic period will not be described in detail. The most striking of these were the increased output of the heart and the decrease in the coefficient of utilization (charts 1 and 2, tables 1 to 6).

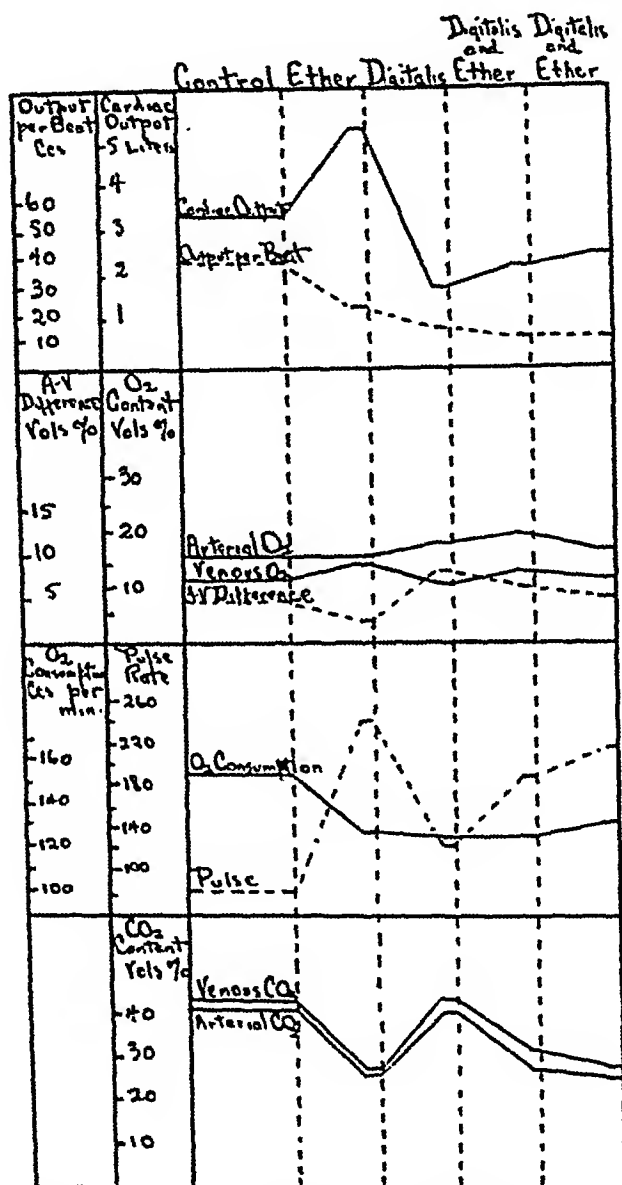


Chart 2.—This figure illustrates the reduction in cardiac output following the administration of digitalis and the slight increase when ether is given, whereas previously ether had caused a great increase in the output. The pulse rate rose during each anesthetic period, the cardiac output per beat decreased, and the carbon dioxide content of the blood fell.

This drawing is purely schematic; time relations are ignored.

The effects of digitalis on the cardiac output of a dog that has not been anesthetized are thought not to be absolute in these experiments, because in most instances the animal had been given ether a few hours

In all, twenty stomachs were examined—twelve were resected for ulcer of the duodenum and ulcer of the stomach, and eight for cancer. Immediately after resection most of the stomachs were introduced into a solution containing one part of solution of formaldehyde and two parts of 80 per cent alcohol. The stomachs resected were opened along the greater curvature. Sections were taken along the whole circumference, in the region of the pylorus, midway between the pylorus and at the proximal edge.

In addition to this systematic study, parts of the tissue from the mucosa of other stomachs were examined, including eight resected gastric ulcers and six resected duodenal ulcers. The sections were stained with hematoxylin-eosin. Special stains were used occasionally to demonstrate points of interest.

I shall give a clinical and pathologic report of one case and present my histologic observations of the other material according to the following classification: (1) normal stomach mucosa, (2) état mammelonné, (3) atypical characteristics of the stomach mucosa, including intestinal islands and erosions, (4) the nature of the inflammation of the stomach mucosa and (5) comment.

Anatomists are somewhat at variance as to the nomenclature of the parts of the stomach. In order to discuss the histologic observations, I shall divide the stomach into the large proximal part—which includes the part long known as fundus and corpus—the pars digestoria, and the distal part, which is smaller, contains the pyloric glands, and is known as the antrum or pars egestoria. The terms fundus, corpus and pars digestoria will be used interchangeably to indicate the proximal part. The pars egestoria and the antrum will also be used interchangeably to indicate the distal part of the stomach.

#### REPORT OF A CASE

*History.*—N. G., white, aged 28, a miner, was admitted to St. Vincent's Hospital on Sept. 15, 1923. He was well until six months before, when he began to vomit. He became much worse a few weeks before coming to the hospital, vomiting frequently, immediately after eating and sometimes several hours later. He never vomited blood or coffee-ground material and never noticed black stools. He never experienced pain in his abdomen. He lost about 40 pounds (18 Kg.) during the last few months before entering the hospital, and was quite weak. His appendix had been removed in 1921.

*Examination.*—He was emaciated. The abdomen was fat; there was a tympanic note and a splashing sound in the region of the epigastrium. There was no rigidity or tenderness in the abdominal wall. The scar of the appendectomy was found in the right lower quadrant.

Gastric analysis showed a high acidity. The hemoglobin content was 72 per cent; the white blood count was 8,350. There was a trace of albumin in the urine.

previously, and this may have altered the result. The cardiac output was the same as in the original control period in two instances, slightly elevated in one and decreased in three instances. In general, the results are confirmatory of the experiments of Harrison and Leonard.

The following is a comparison of the cardiac output during ether anesthesia in the digitalized dog with the figures obtained under other conditions:

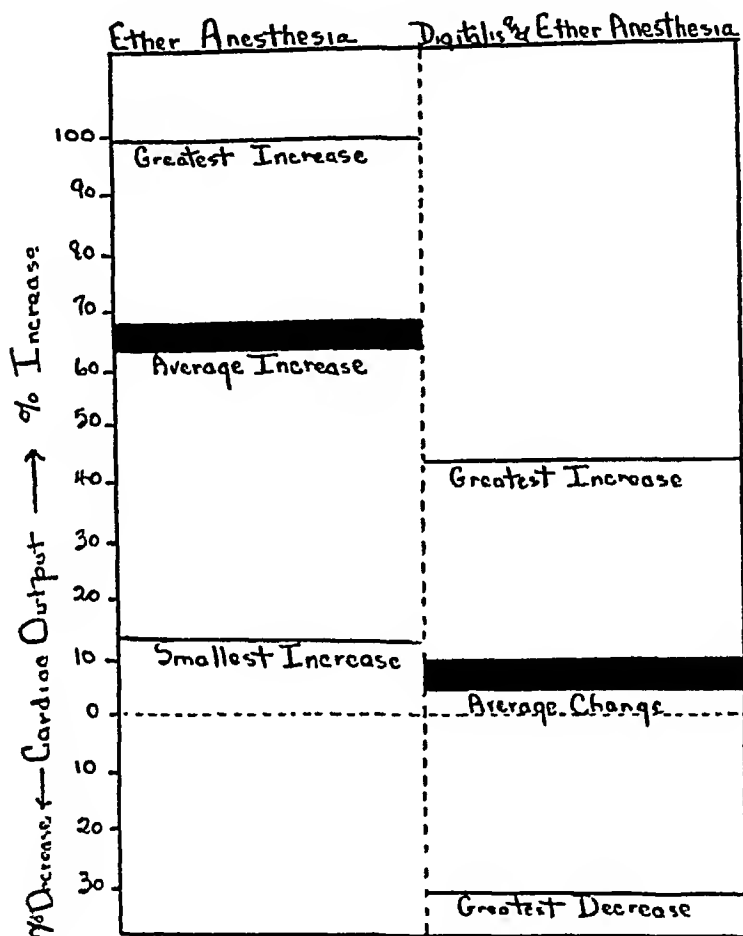


Chart 3.—The percentage change in cardiac output during the first anesthesia period was determined by comparing the figure for cardiac output per minute with the one obtained during the control period, and the cardiac output during the second anesthesia period was compared with that following the administration of digitalis. The average change was computed from the figures in all of the experiments. The smallest change during ether anesthesia without digitalis was greater than the average change during ether anesthesia in the digitalized dog.

1. The cardiac output remained essentially the same as in the original control period in six determinations, rose slightly in one, fell slightly in three and decreased definitely in two instances. The average cardiac output per kilogram of body weight was only 4 cc. different from that of the original control period.

base; the lymph follicles were irregular and increased in size; there were also groups of round cells. The interstitial tissue between the alveoli was increased; dark-stained epithelium with goblet cells were found near these groups of glands. Some of the round cells penetrated into the muscularis mucosa (fig. 1).

Sections made through the same area demonstrated an ulcer which was not found at the examination of the gross specimen with the naked eye. The ulcer was about 2 mm. in diameter. The whole muscular wall was destroyed and was replaced by a connective tissue rich in blood vessels. The area proximal to the lumen consisted of connective tissue and of granulation tissue, some

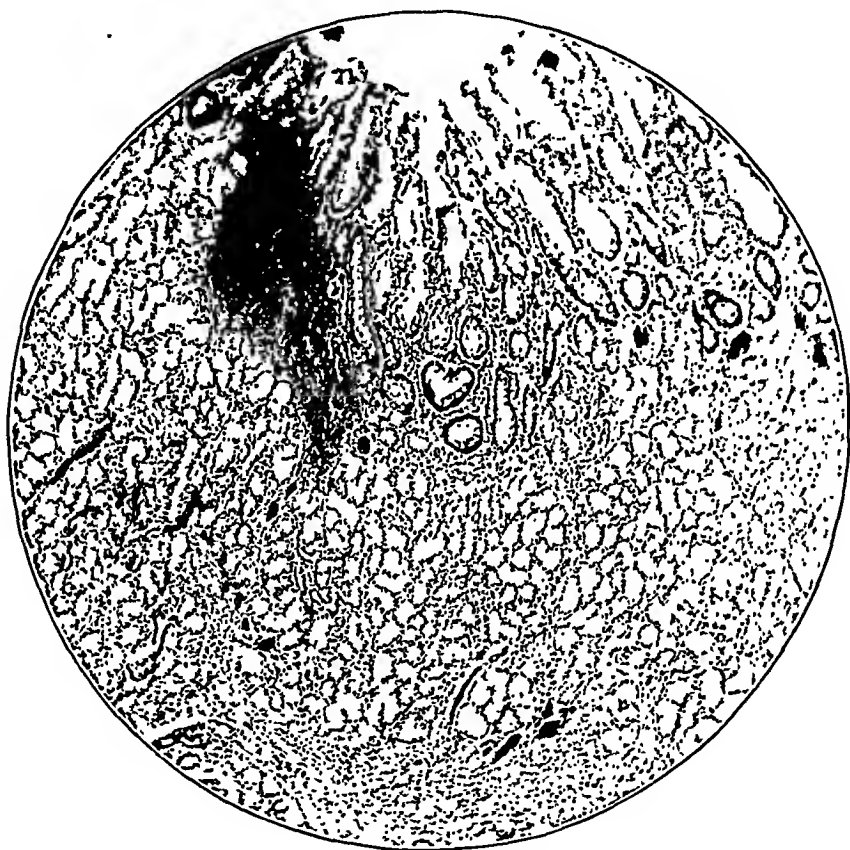


Fig. 1.—Hypertrophic form of gastritis, showing the alveoli with the hypertrophy of the muscularis mucosa growing between the groups of alveoli (pseudopyloric glands of Stoerk); also small islands of intestine-like mucosa with infiltration of round cells.

of which appeared to be new and rich in blood vessels. There were thick-walled arteries and several neuromas in this granulation tissue. There was a necrotic exudate at the base of the ulcer. The adjacent mucosa consisted of branching glands which looked like Brunner's glands, or the pseudopyloric glands described by Stoerk (fig. 1). Parts of the muscle fibers around the ulcer seemed to be destroyed. Two large nerves were found embedded in the muscles. Accumulation of round cells penetrated deep into the muscularis mucosa, and some of the lymph follicles were also found beneath it. In some parts they penetrated through the wall of the glands into the lumen. Small areas of dark-stained epithelium with goblet cells were also found. A conical-shaped defect

2. The cardiac output was less in every instance than that during the original anesthetic period. The average figure for the cardiac output per kilogram of body weight was 243 cc. during the first anesthetic period, while that during ether anesthesia following the administration of a digitalis preparation was only 147 cc. The largest figure obtained during the latter period was smaller than the average figure during the first anesthetic period. These alterations are represented in terms of percentage of change in chart 3.

3. The changes which ether anesthesia produced on the cardiac output of the digitalized dog are almost negligible. This is demonstrated by the fact that the average cardiac output per kilogram of body weight was 148 cc. before the administration of ether, and 147 cc. during the period that the animal was under the influence of an anesthetic.

Changes in pulse rate, oxygen consumption and carbon dioxide content were in general similar to those during the anesthetic period without digitalis, but the coefficient of utilization was greater in each instance.

#### COMMENT

In view of the fact that experiments were performed on trained dogs as well as on those anesthetized with morphine, and that the results were similar in each instance, it seems justifiable to state that digitalis prevents an increase in the cardiac output of the anesthetized normal dog. It is known that most drugs have the same type of effect on man as on the dog. In order to discuss the possible general significance of this experimental work, it is necessary to assume that such a relation exists because of the difficulties and dangers in determining the cardiac output of man.

Recent work supports the view that digitalis exerts its beneficial effect by maintaining a balance between the two ventricles. Cushman<sup>6</sup> stated that digitalis exerts little influence on the blood pressure. It has been found in studying the effect of ether anesthesia on the cardiac output that all of the increase could not be due to the effect of changes in the reaction of the blood, and that there is a direct stimulating action by ether on the heart was assumed. Practically no increase in cardiac output resulted when ether was administered to dogs that had received digitalis. If it is granted that digitalis decreases the cardiac output by direct action on the heart, this is further evidence that part of the elevation in the cardiac output during ether anesthesia is caused by a specific stimulating effect of the anesthetic on the heart. Determinations of the hydrogen ion concentration were not made in these experiments, but it cannot be assumed that digitalis prevents the usual increase, especially since the carbon dioxide content behaved in the usual manner. It seems

<sup>6</sup> Cushman, A. R.: *The Action and Uses in Medicine of Digitalis and Its Allies*, London, Loeberman, Green & Co., 1925, p. 117.

except that in some parts the tubules or foveolae were not so long, and the glands contained parietal cells. In some areas the accumulations of round cells and lymph follicles occupied a part of the mucous membrane. In certain areas, numerous parietal cells were found in the body and fundus of the glands, in others, only remnants of the foveolae or tubules were left, and the bodies and the fundi of the glands appeared to be replaced by groups of round cells. There were indentations in the mucosa reaching the muscularis. Where the mucosa reached the muscularis mucosae and the groups of round cells, the epithelium was dark-stained and proliferating.

Sections obtained from the proximal end of the posterior wall of the stomach, in the area of the corpus, demonstrated foveolae which were about



Fig. 3.—Small defect in the depth of the glands, healed by single layer of dark-stained epithelium.

one fifth of the length of the glands; these appeared to be typical fundus glands with chief and parietal cells. There were only a few round cells and scanty interstitial tissue between the foveolae and tubules. There was some accumulation of round cells in the places where the mucosa sank down. Here the islands consisted of a few foveolae wide and deep and dark-staining, but glands proper were not seen. In the anterior wall of the stomach, at the area where resection was made, I found the same picture as in the posterior wall, with the exception that there was an area in which the fundus glands appeared to be infiltrated by round cells.

Midway between the pylorus and the resected proximal end, the glands had very deep foveolae admitting many branched alveoli with light-staining epi-

probable that the depressing effect of digitalis on the output of the heart counteracts part of the stimulating influence which ether produces. The heart of the dog that has received digitalis is much less subject to fluctuations in output, as is demonstrated by the small variation in output when ether is administered. This is shown in chart 4. It is to be noted not only that the average of all the figures for cardiac output per kilogram of body weight are practically identical, but also that the highest and lowest figures obtained in all of the experiments fall within a rather small range.

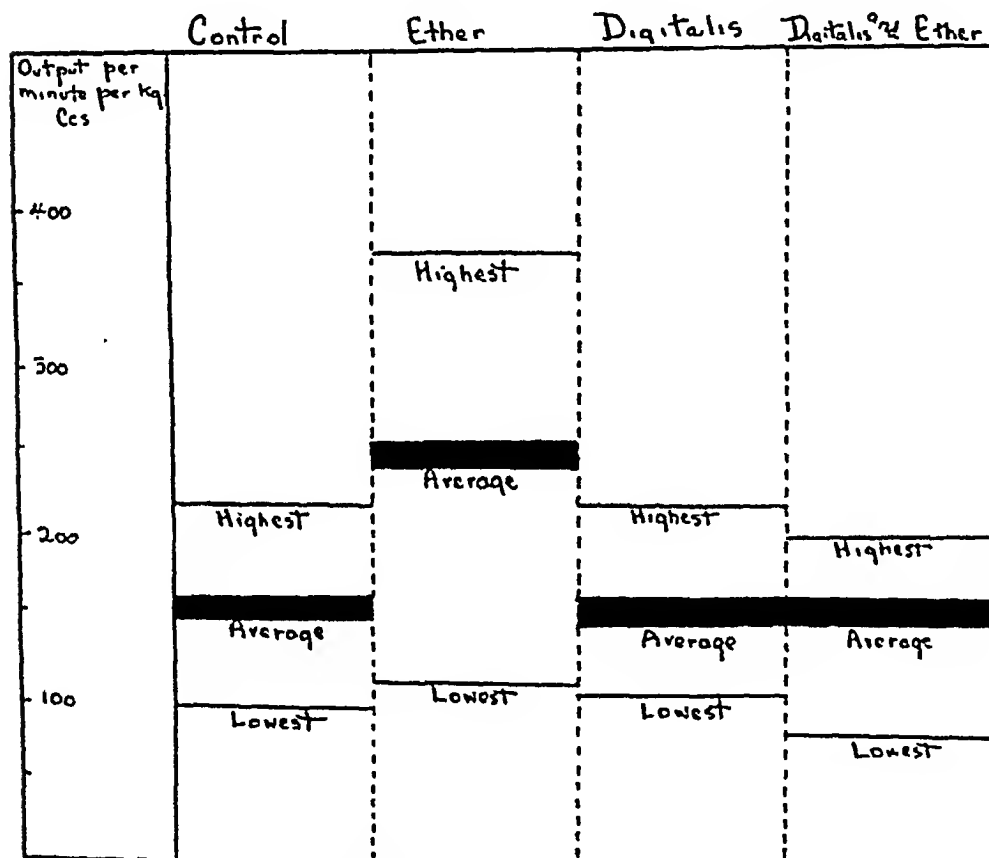


Chart 4.—This is a composite chart of all experiments. The highest and lowest values per kilogram of body weight during the four phases of the experiments are charted on the thin lines. The average output is not the mean of the highest and lowest values, but is the average of all the figures. It is thought that the cardiac output during the control period following the giving of digitalis would have been lower if ether had not been administered previously. There is a striking rise in cardiac output during ether anesthesia without digitalis.

Harrison and Leonard have found that the elevation in the cardiac output which is present in dogs with hyperthyroidism and anemia can be decreased by the administration of digitalis. They express the belief that this drug would probably be valuable in preventing cardiac failure from overstrain in these conditions. Apparently, digitalis establishes a



areas a few millimeters in diameter (fig. 4). This condition has been called, by normal anatomists and pathologists, *status mamillaris*, *état mammelonné* or *catarrhus verrucosus* (see later *état mammelonné*).

Microscopic examination of the mucous membrane reveals numerous small openings—the *foveolae gastricae*. These are depressions into which the glands of the stomach open. The *foveolae gastricae* measure one fourth to one fifth of the depth of the fundus glands. In the region of the pylorus they are much deeper and may even reach the *muscularis mucosae*. The gastric crypts and folds between them are covered with a long, slender epithelium, the cells of which are somewhat conical. They extend downward in a curve toward the basement membrane, while the broad part of the cell is directed toward the free surface. The latter portion forms a cuplike plug which gives a chemical reaction for mucus, the basal part containing the nucleus being richer in protoplasm.

Oppel,<sup>10</sup> who examined this type of epithelium in vertebrates and mammals, found that, as in man, the cells consist of two differentiated parts—a basal protoplasmic part and a peripheral part belonging to the surface, which he named *Oberende*. Ebner and Oppel have demonstrated that the open cells found on the surface of the epithelium are artefacts. Cells of the superficial mucosa of the stomach, like other mucous cells, are easily injured. The superficial part of the cell swells and flows in part or altogether from its free end.

The glands of the stomach mucosa are usually divided into the cardiac glands, fundus glands and pyloric glands. Aschoff<sup>9</sup> and Oshikawa<sup>11</sup> have recently called attention to the form of glands in the region of the isthmus, which they named the intermediate glands. There is doubt as to the nature of these glands, and I shall return to them in the presentation of the pathologic picture of the stomach mucosa (see pseudopyloric glands).

The cardiac glands are branched tubular in type and occupy an area varying in width from 0.5 to 4.3 cm. (Bensley<sup>12</sup>). The cells are somewhat similar to those of the pyloric glands and to the mucous chief cells of the fundus glands. Some of the lining cells, however, contain zymogen granules similar to those of the chief cells of the fundus glands. Occasionally a few parietal cells are present.

10. Oppel, A., quoted by Harri, Paul: Ueber das normale Oberflächen-Epithel des Magens und über Vorkommen von Randsaum-Epithelien und Becherzellen in der menschlichen Magenschleimhaut, *Arch. f. Mikrosk. Anat. u. Entwickl. geschichte* 58:684, 1901.

11. Oshikawa: Beiträge zur Histologie des Magens und der Magengeschwüre, *Virchows Arch. f. path. Anat.* 248:217, 1924.

12. Bensley, R. R.: Reference Handbook of the Medical Sciences, ed. 3, New York, William Wood & Company, vol. 7, 1917, p. 943.

balance at a lower level and probably protects the weaker ventricle from overstrain by the stronger one. For the same reason it seems that the preoperative administration of digitalis should be of definite therapeutic value under the following circumstances:

1. In patients suffering from conditions known to be associated with an increased cardiac output. Such conditions are hyperthyroidism, severe anemia, anoxemia<sup>7</sup> and probably other disorders still to be investigated.

2. In patients of all ages with hypertension or organic heart disease.

3. In elderly and debilitated patients.

Marvin, Pastor and Carmichael<sup>8</sup> have concluded from electrocardiographic and blood pressure studies during surgical operations and convalescence that routine employment of digitalis in patients with normal hearts is not necessary.

Since it is well known that shock results in a decrease in the cardiac output, the administration of digitalis should not be delayed until after this condition is produced. The rôle of digitalis should be to prevent acute circulatory failure rather than to combat it; hence, if digitalis is given, it should be administered previous to the anesthetic. It is felt that when given under such conditions, digitalis may protect the heart from overstrain by increasing its tonus and diminishing the contractility. Digitalis has been used rather generally in the past in the preparation of patients with heart disease for operation, but usually with a different aim. For example, Richardson<sup>9</sup> stated that digitalis should be used to alleviate the period of depression following operation. Rather than this, it seems that digitalis should serve to prevent strain on the heart at the time of operation and by this means to prevent the depression which might follow. In a previous paper,<sup>10</sup> it was shown that the administration of alkali partially prevented the increase in cardiac output. Digitalis is preferable to alkali for two reasons: 1. The desired dosage of digitalis is fairly well known, whereas the amount of alkali which is needed is dependent on the acidosis, which cannot be estimated with accuracy previous to the operation. 2. Digitalis exerts its influence essentially on

7. Harrison, T. R., and Blalock, A.: Studies on the Effects of Hyperthyroidism, Anemia and Anoxemia on the Cardiac Output, unpublished observations.

8. Marvin, H. M.; Pastor, R. B., and Carmichael, Mabel: Electrocardiogram and Blood Pressure During Surgical Operation and Convalescence; Effect of Routine Preoperative Digitalization, *Arch. Int. Med.* **35**:782 (June) 1925.

9. Richardson, F. L.: Heart Serums in Anesthesia, *Am. J. Surg. anesthesia* suppl. **33**:100 (Oct.) 1910.

10. Blalock, A. (footnote 1, second reference).

ing zone. The nucleus is found at the junction of the two zones and possesses one or two oxyphile nucleoli. The chief cells of the neck are characterized by the absence of chromidial substance and zymogen granules which are in the basal part of the chief cells of the tubule. According to Bensley<sup>12</sup> they are irregular columnar structures and slightly smaller than the chief cells of the body of the gland. The contents of the cell appear clear in hematoxylineosin stain. The nucleus is situated in the proximal attached part of the cell.

These are evidently the cells first described by Zimmermann<sup>15</sup> as possessing a light-staining plasma and a flat nucleus at the bottom of the cell. Zimmermann believed these were mucus-secreting cells similar to those which Kupffer described in the mucus glands of the stomach. According to Bensley,<sup>12</sup> these mucus-secreting cells may be found in a few glands to reach entirely to the bottom and to replace the chief cells throughout the whole gland. Such glands contain a few parietal cells and have a larger lumen.

I am of the opinion that such glands represent the frequent proliferated epithelium of the lacunae which generally displace the specific cells not only in the neck, but also as far as to the base. They represent the glands described by Stoerk<sup>4</sup> (fig. 1), which are characterized by numerous branchings with the lining of cells appearing clear in hematoxylin.

Many histologists believe that there is not a sharp transition between the fundus and the pyloric glands. Radasch,<sup>16</sup> after examining several human stomachs and several stomachs of rabbits, came to the conclusion that there is an abrupt decrease or cessation of the acid cells, and that the branched tubular glands of the pylorus make their appearance suddenly.

In the examination of my own specimens, I have observed that the fundus glands cease abruptly. They are replaced by the branched normal pylorus glands or those demonstrating pathologic changes.

The pyloric glands open into crypts which are much deeper than those of the fundus region. The tubules of the pyloric glands are more branching, less closely set and contain more connective tissue between them. The cells lining the foveolae of the pyloric glands are cylindrical and possess an oval nucleus much like that of the cells found in the bottom of the foveolae of the fundus glands. Those lining the terminal branches of the pyloric glands are more cuboidal, resembling those of the neck of the fundus glands. These are light-staining mucus cells. The parietal cells are either altogether absent or rare.

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15. Zimmermann, quoted by Bensley, R. R.: Reference Handbook of the Medical Sciences, ed. 3, New York, William Wood & Company, 1917, vol. 7, p. 943.

16. Radasch, H. E.: Acid Cells of the Stomach, *Internat. J. Gastro-Enterol.* 1:24, 1924.

# STOMACH MUCOSA IN ULCER AND IN CARCINOMA

HISTOLOGICAL STUDY \*

MOSES F. STEINBERG, M.D.

SENIOR, CH.

Former histologic studies of the stomach mucosa have been based chiefly on the examination of post-mortem material. Later investigators have introduced fixing fluids into the stomach at various periods after death in order to prevent self-digestion of the stomach mucosa. There are on record the results of examinations of stomachs immediately after capital punishment (Kaufmann<sup>1</sup>). Reports of the results of examinations of stomachs resected for cancer (Matti<sup>2</sup>), or of examinations of parts of stomachs removed during gastrectomies (Heyrovsky<sup>3</sup>) have also appeared at various times. Only during the last few years have surgeons treated ulcers of the stomach and duodenum by gastrectomy. Stoerk,<sup>4</sup> Konjetzny,<sup>5</sup> Moszkowicz<sup>6</sup> and Orator<sup>7</sup> have availed themselves of the surgical material and have made comprehensive reports of their observations.

The work reported in this paper was started at the University of Vienna, department of histology and pathology, under the direction of the late Professor Stoerk. The material examined was obtained chiefly from patients operated on by Professor Binswanger. Some of the last series of the stomachs examined were those of patients on whom I had performed operations.

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\* From the Pathology and Physiology Departments of the University of Oregon Medical School.

1. Kaufmann, Marie: *Über das Vorkommen von Dilegerellen im Pylorus und Duodenum des Menschen*, Anat. Anz. **28**:465 (May 5) 1906.

2. Matti, H.: *Beitrag zur Kenntnis des Magencarcinoms. Untersuchungen über die Ursachen des veränderten Chemoismus bei Fällen von Magencrebs*, Deutsche Ztschr. f. Chir. **104**:425, 1910.

3. Heyrovsky, Hans: *Histologische Untersuchungen der Magenschleimhaut bei Ulcus Ventriculi und Carcinom*, Deutsche Ztschr. f. Chir. **122**:362, 1913.

4. Stoerk, Oscar: *Ueber Gastritis Chronica*, Wien. klin. Wchnschr. **35**:855 (Nov. 2) 1922.

5. Konjetzny, G. Ernest: *Chronische Gastritis und Duodenitis als Ursache des Magendodenal geschwürs*, Beitr. z. path. Anat. u. z. allg. Path. **71**:595, 1923.

6. Moszkowicz, Ludwig: *Zur Histologie des ulcusbereiten Magens*, Arch. f. klin. Chir. **122**:444, 1922.

7. Orator, Victor: *Ueber den Ulcus und Carcinommagen*, Wien. klin. Wchnschr. **16**:425 (April) 1925. *Beiträge zur Magenpathologie. IV.* Arch. f. klin. Chir. **134**:663, 1925.

glands are increased in number, and there is an elongation of the gland at its central part. At the base, the gland turns on itself, the elongation of the basal part of the tubule being prevented by the muscularis mucosae. Each mammillated protuberance seems to have an axial vessel (fig. 4). There is an increase in the number of parietal cells, and there are pictures in which the parietal cells overshadow the chief cells (fig. 6). Normally the parietal cells are triangular, oval or wedge-shaped, but in this condition they are round and are found to lie directly

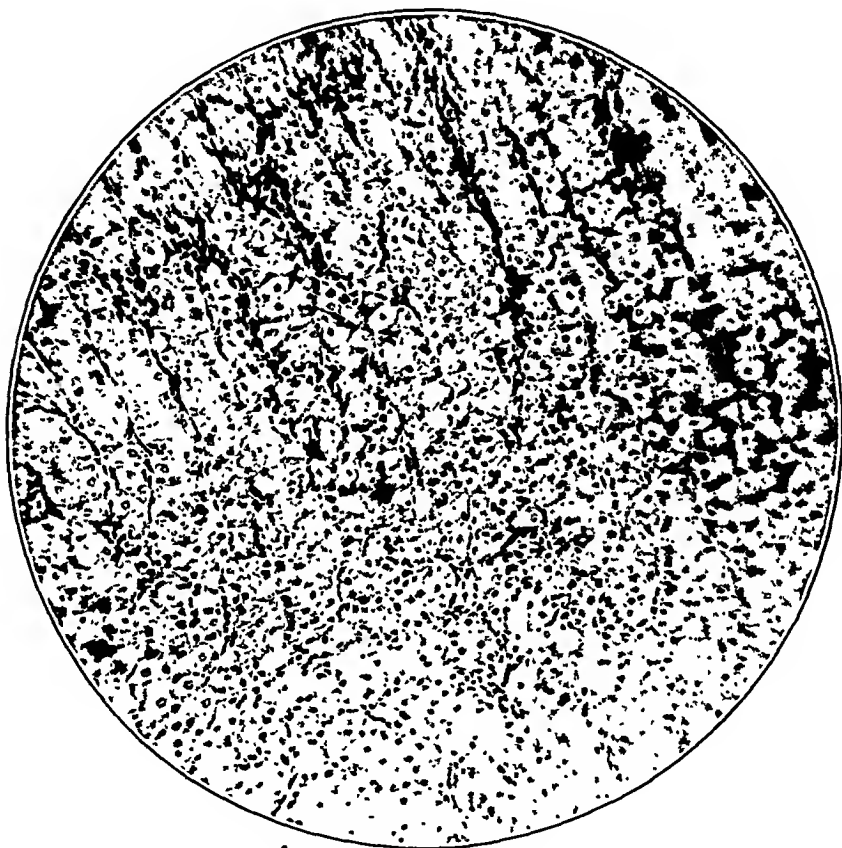


Fig. 6.—Low power magnification of état mammelonné, showing the numerous round parietal cells.

in contact with the lumen (fig. 5B). Droplets surrounding the nucleus can be seen. The parietal cells bulge and may escape, filling the lumen.

In état mammelonné of the stomach mucosa there is little connective tissue between the tubules, and the lymph follicles are few and mostly triangular, a condition which distinguishes état mammelonné typical of the fundus from the condition in the pyloric mucosa, in which numerous round lymph follicles with germinal centers indicate an active inflammatory condition. The areas of gastritis may be interspersed with the areas of état mammelonné in the mucous membrane of the fundus, and occasionally there may be inflammatory changes characteristic of gastritis invading the état mammelonné.

*Röntgen-Ray Examination* (Dr. Diemer).—Although the patient said that he had not eaten for fifteen hours, a quantity of material was observed in the stomach. Röntgenograms taken after the ingestion of barium meal revealed that the stomach was increased in size and capacity and was boat-shaped on account of the dilatation. A pathologic gastric condition was not otherwise demonstrated.

The first portion of the duodenum did not fill. Only a small stream of barium was observed in the duodenum. Röntgen-ray examination indicated obstruction as a result of chronic ulcers ulcer of the duodenum. Adhesions of the stomach were also considered.

*Operation and Course*.—I operated on this patient on September 17, after two days of frequent lavage of the stomach. Anterior spinal-aneesthesia was used. The pylorus was thick, dilated with numerous thick adhesions about the antrum and duodenum. When the distal part of the stomach was resected, two ulcers were found in the first part of the duodenum. A modification of Billroth's second operation (Hodder-stated gastrectomy) was performed. The patient felt well for a few days, but later developed symptoms of broncho-pneumonia; these, however, soon cleared up. The patient did not vomit. He gained 10 pounds (4.5 kg.) during his stay, and left the hospital on October 24.

I saw the patient two months later. He had gained 40 pounds and had no symptoms of any kind. He was working as a laborer and did not adhere to any particular diet. A roentgen-ray examination made by Dr. Diemer at that time revealed that the esophagus was normal; in other words, it did not dilate at its distal end as a compensatory measure for the lessened capacity of the stomach. Apparently, at least one half of the stomach had been removed. The remaining portion presented perfectly smooth borders. A pathologic gastric condition was not indicated by any defect in filling. It was observed that the caudal part of the stomach developed a compensatory peristaltic action, emptying before immediately and continued in a normal moderate manner. The stomach was freely movable, and a pathologic condition of the duodenum was not evident.

The chemical examination at this time showed that the stomach did not contain free acid.

*Pathologic Report*.—The gross examination of the resected specimen revealed a deep indurated ulcer on the anterior wall of the first part of the duodenum with thickening of the serosa about it. There was a scar with evidence of previous ulceration near the large ulcer.

Microscopic examination of the mucosa in the region of the antrum, 1 cm. proximal to the pyloric ring, demonstrated a fan-shaped arrangement of the groups of glands, the foveolae being long and straight. Only two or three alveoli opened into the tubule; the cells lining the foveolae were light-staining; the interstitial tissue between the foveolae and the tubules was rather scant. The muscularis mucosa reached high between the groups of glands; the lymph follicles were triangular and not numerous. Deep valleys reaching the muscularis mucosa appeared where the epithelium was desquamated and where there was infiltration of round cells.

Dark-staining epithelium suggested previous destruction of glands and a process of regeneration; otherwise the glands appeared normal. On the inferior surface, about 1 cm. from the pyloric ring, some glands appeared normal, and corresponded to the description given. There were, however, groups of glands with tall foveolae. Branched alveoli were found in connection with each tubule, the cells lining the alveoli were cuboidal, the nuclei were small, found at the



Fig. 8.—The distal part of the stomach resected for duodenal ulcer. The mucosa is only partially granular; the granules are not pronounced. Smooth areas of mucosa predominate.

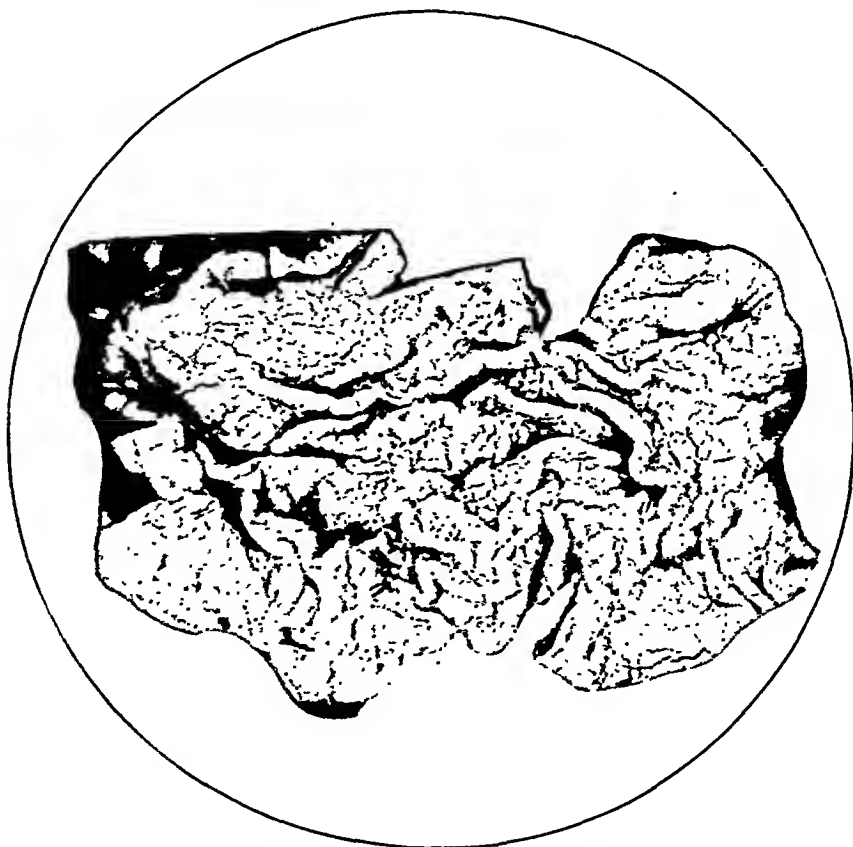


Fig. 9.—Distal end of a stomach resected for duodenal ulcer. Mucosa extremely granular; the granules are irregular in size and shape; smooth areas of mucosa found.

separated areas of glands and penetrated into the accumulation of round cells near the muscularis mucosa: on one side remnants of the glands and on the other side dark-stained young epithelium attempted to bridge the defect.

The blood vessels in the scar were thick-walled, some were obliterated, and there were a few islands of round cells and polymorphonuclear leukocytes.

Sections taken through the posterior surface of the antrum, about 5 cm. from the pylorus, demonstrated fan-shaped areas of glands. The foveolae or tubules were straight and long, and the glands were not branching. These looked like normal pyloric glands. Close to the areas just described I found some in which the follicles were increased in number and size; where was also an



Fig. 2.—Islands of dark-stained intestine-like epithelium taken from the same section as figs. 13 and 18, representing a healed erosion.

accumulation and infiltration of round cells between the glands and the muscularis mucosa and between the tubules of the glands. The glands were branching with light-staining epithelium. There were also islands of tubules of dark-staining epithelium, some of which appear high columnar, while others contained goblet cells (fig. 2). In other places, the mucosa sank to the accumulations of round cells and polymorphonuclear leukocytes and appeared to cover the sunken areas by one layer of high columnar epithelium. Where the epithelium reached the accumulation of round cells, it appeared desquamated, and the lymphocytes, leukocytes and plasma cells penetrated through the mucosa into the lumen (fig. 31).

The structure of a section from the anterior wall of the stomach, the same distance from the pylorus, was the same as that of the sections just described.





Fig. 10.—Pronounced gastritis with remnants of glands present and groups of round cells. Low power magnification.

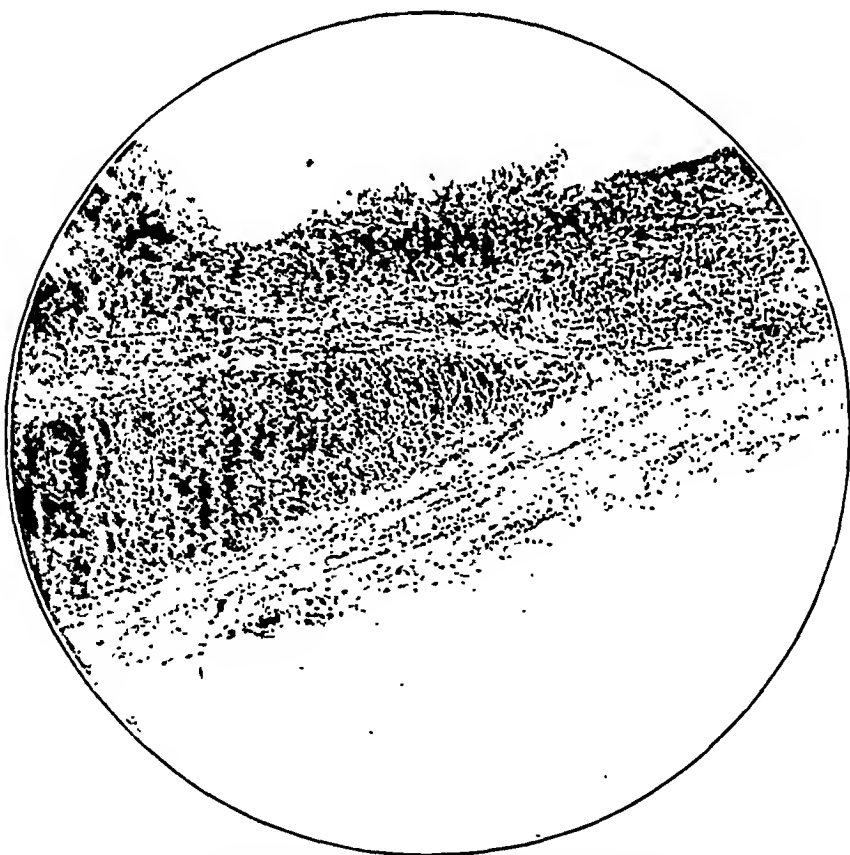


Fig. 11.—An extreme degree of gastritis, with only one layer of desquamated epithelium covering the interstitial tissue. Low power magnification.

thelial cells. The follicles were greatly increased in size and number and possessed germinal centers; there were many areas of proliferating dark-stained epithelium, also islands of intestine-like mucosa. Some of the follicles were spread wide apart by an accumulation of lymph follicles, polymorphonuclear leukocytes and plasma cells.

#### THE NORMAL STOMACH MUCOSA

The mucosa of the stomach is a maze of irregular folds. In the fixed state, there are four longitudinal folds spreading out fan-shaped on the lesser curvature into the pyloric canal. When the stomach is distended, most of the folds disappear. According to Tandler,<sup>8</sup> the part of the stomach containing the Magenblase is free from folds. The color

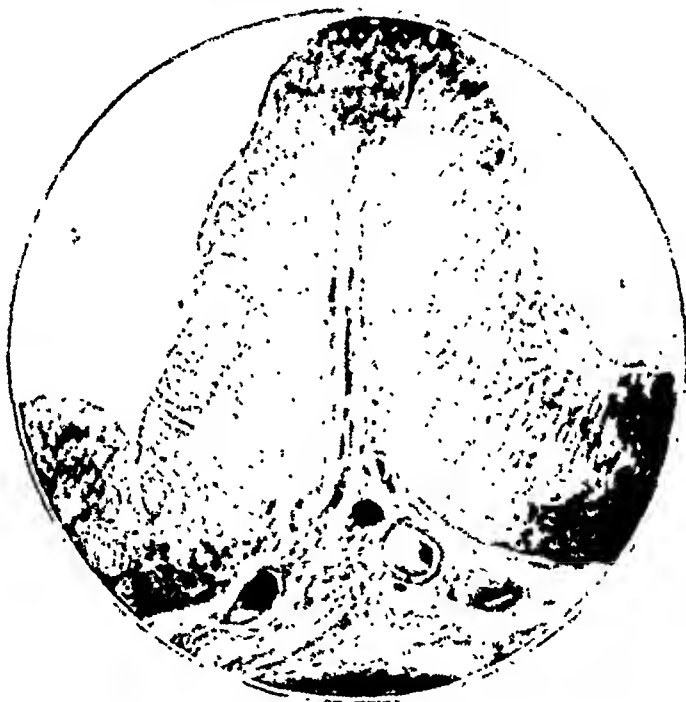


Fig. 4.—Low power magnification of one mammilla of état mammeloné with axial vessel.

of the normal stomach mucosa is pinkish. Aschoff<sup>9</sup> calls attention to the difference in color between the gastric pathway and the rest of the stomach.

In the condition of distention, when the folds disappear, one can see small areas a few millimeters in width, the *areae gastricae*, which are indistinctly marked off by irregular sulci. In the large proximal portion of the stomach mucosa of the adult, there are numerous small elevated

8. Tandler, Julius: *Lehrbuch der systematischen Anatomie*, Leipzig, F. C. W. Vogel, 1923, vol. 11, p. 131.

9. Aschoff, Ludwig: *Lectures on Pathology*, New York, Paul B. Hoeber, 1924, p. 279.

normal glands at the bottom of these islands. I shall discuss the significance of the islands of heterotopic or atypical glands in connection with the erosions.

There is a prevailing form of gland which Stoerk called the pseudopyloric type. The tubules are pushed apart by interstitial elements with lymphocytes and leukocytes. The fundi of the glands are branching and irregular. Muscle fibers from the muscularis mucosa and the connective tissue penetrate deeply between the glands. The cells lining the



Fig. 14.—High power magnification of figure 17 to demonstrate the dark-stained syncytium-like area of epithelium attempting to heal the defect.

branching alveoli are transparent and cuboidal with the nucleus in a marked basal position. One frequently finds that the lymph follicles are numerous and large and possess a germinal center in the region of these glands. This form of gland is not only found in the antrum mucosa, but may also be found remote from the pylorus in the fundus of the stomach displacing the typical glands. The lumina of such glands are occasionally filled with lymphocytes, leukocytes and plasma cells (fig. 1).

Oshikawa<sup>11</sup> and Aschoff<sup>9</sup> have described a new form of gland found in the isthmus of normal stomachs, which they named the intermediary

The fundus glands occupy the larger proximal part of the stomach mucosa. The tubules in these glands are only moderately branched and are vertical. They are close to each other and are separated by a scant amount of connective tissue. Each foveola receives from three to five or more branched tubules. The small part of the tubule opening directly into the foveola is narrow and is known as the neck. The terminal blind end is called the fundus, and the intermediate portion is known as the body of the gland. The glands proper are lined with two kinds of cells, the chief and the parietal cells. The chief cells have been described by Heidenhain<sup>13</sup> and called the *Hauptzellen*, while Rollett<sup>14</sup> named them *Adenomorphzellen*. The parietal cells were called by Heidenhain the *Belegzellen* and Rollett the *Delomorphzellen*.

The parietal cells are larger than the chief cells; they are more irregular, triangular or oval, and show an affinity for acid stains (fig. 5A). Normally these cells are more numerous in the body and in

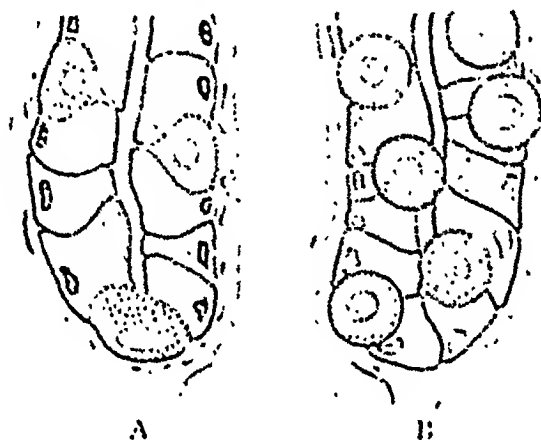


Fig. 5.—A, diagram of a normal fundus gland with parietal cells of triangular form; B, gland of *cat mamelonné* with round parietal cells.

the neck of the gland. They rest on the basement membrane of the tubule, frequently forming a protuberance beyond the even line of the remaining cells, and occasionally giving the appearance of being extra-glandular. They contain one or more nuclei, and with certain stains display intracellular canaliculi connecting the cells with the lumen of the gland by a narrow duct.

The chief cells are wedge-shaped columnar structures which form a lining for the tubule, being displaced in varying degrees by the parietal cells. The chief cells when stained in hematoxylineosin have two well formed zones: a basal deep-staining portion and a superficial light-stain-

13. Heidenhain, R., quoted by Bensley, R. R.: Reference Handbook of Medical Sciences, ed. 3, New York, William Wood & Company, 1917, vol. 7, p. 943.

14. Rollett, A., quoted by Bensley, R. R.: Reference Handbook of the Medical Sciences, ed. 3, New York, William Wood & Company, 1917, vol. 7, p. 943.

The foregoing is a description of the normal mucosa. It is important to have a clear idea of what is normal and what belongs to the pathologic. The adult stomach is seldom found to be free from heterotopic or proliferated changes. Orator,<sup>7</sup> who made an extensive study of what he thought were normal and pathologic stomachs, came to the conclusion that the normal mucosa of the fundus region is characterized by foveolae which represent only from 25 to 30 per cent of the whole thickness of the stomach mucosa; that a production of mucus in the fundus glands is slight, and that only in the region of the stomach pits is there a slight cellular infiltration.

Only occasionally is there a lymph follicle with a germinal center in the submucosa. The pyloric glands of the stomach mucosa are characterized by deep foveolae which represent from 60 to 70 per cent of the thickness of the mucosa. These glands secrete mucus in abundance. There is a light cellular infiltration not only in the region of the pit of the stomach, but also in the region of the deeper structure of the glands. In many pathologic stomachs examined, I found areas of mucosa resembling the normal mucosa described in textbooks on histology.

#### ÉTAT MAMMELONNÉ

I was unable to find any true or comprehensive picture of the condition frequently described as *état mammelonné*. Aschoff,<sup>17</sup> Borst<sup>18</sup> and other authorities consulted, speak of this condition as *catarrhus verrucosus*. Aschoff,<sup>17</sup> in his textbook, states that the *état mammelonné* is found in the region of the antrum pylori. Bassler<sup>19</sup> describes it as representing the rough, mammillated appearance limited to the mucosa of the distal part of the stomach. Tandler,<sup>8</sup> in his recent textbook on normal anatomy, brings out the fact that polygonal areas in the stomach mucosa may be pronounced and elevated, and that the condition is then called *status mammillaris*.

Stoerk<sup>4</sup> gives a true description of the histologic picture of *état mammelonné*. He points out that it is not an actual gastritis but a hypertrophy. Many stomachs which I examined present this picture, which is limited to the proximal part. As a rule, the distal part of the stomach shows the microscopic changes of gastritis. The elevations, which cover the mucous membrane of the fundus area of the stomach, are fairly uniform. An inflammatory process is not found microscopically. The

17. Aschoff, Ludwig: *Pathologische Anatomie*, ed. 6, Jena, Gustav Fischer, 1923, vol. 2.

18. Borst, Max.: *Pathologische Histologie*, Leipzig, F. C. W. Vogel, 1922, p. 121.

19. Bassler, Anthony: *Diseases of the Digestive System*, Philadelphia, F. A. Davis Co., 1922, vol. 1, p. 534.





